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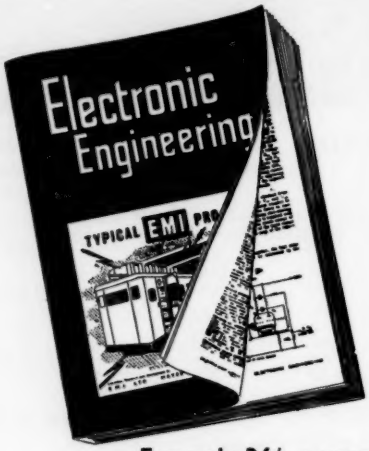

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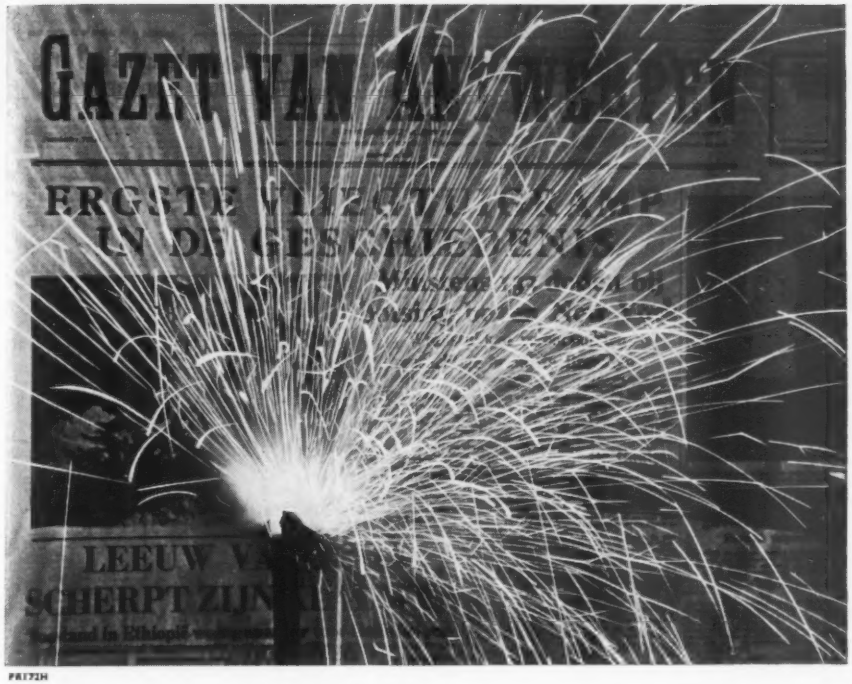

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THE Council of the British Association for the Advancement of Science have, at the invitation and with the financial backing of the Carnegie United Kingdom Trust, prepared a new edition of *The Directory of Natural History Societies* which was first published in 1948 by the Amateur Entomologists Society.

The Directory covers archaeological, astronomical, biological, botanical, geographical, geological, meteorological and zoological societies, both national and local amateur bodies —and other cognate societies. The information given for each society is listed under the following headings: title and address, name and address of Secretaries, aims and objects, conditions of membership, amenities, meetings, publications and affiliations. Societies are arranged alphabetically under the main headings of natural history, archaeology, archaeology and natural history, societies with general interests, geology, astronomy, and meteorology. The arrangement of the societies within the sections is strictly alphabetical according to the titles supplied by the Secretaries. There is a final geographical reference section in which the names of the societies are listed alphabetically according to counties.

Copies of the *Directory* are available to all Natural History and Field Study Societies at a price of 10*s*. (post free) from The Secretary, British Association for the Advancement of Science, 18 Adam Street, Adelphi, W.C.2.

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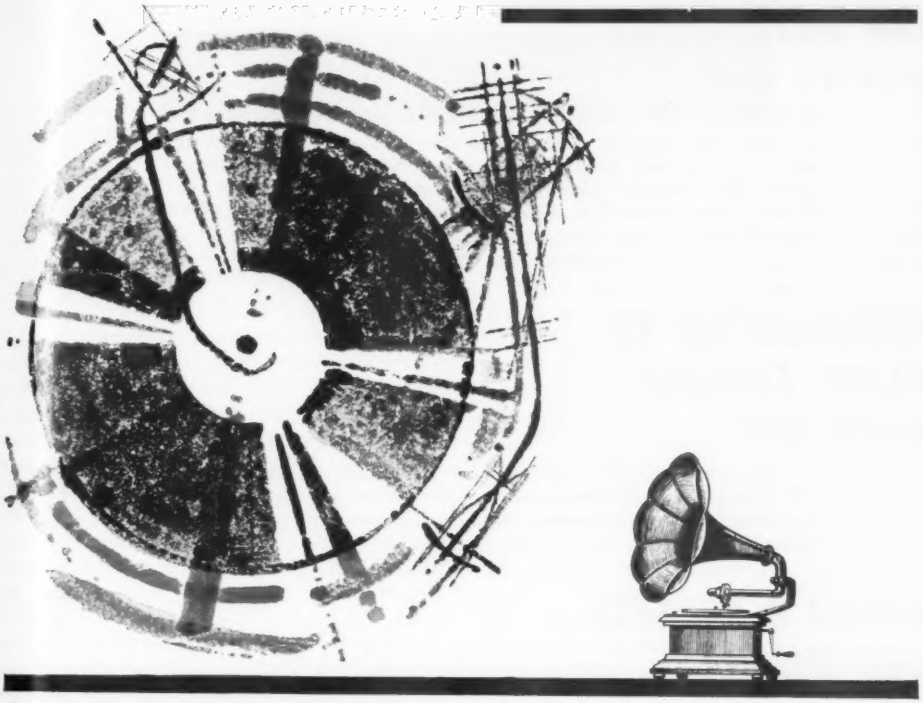

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Edited by K. DURHAM

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Notes and Comments

THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

By Sir Rudolph Peters, M.C., F.R.S.
President, I.C.S.U.

I.C.S.U. is probably known best through one of its special committees, which looked after the International Geophysical Year (I.G.Y.)—this committee was called C.S.A.G.I; it has now become C.I.G. (Comité International de Géophysique), which is concerned with the publication of results and other finalizing activities of the I.G.Y.

I.C.S.U. came into existence in 1931 when the International Research Council was reorganised. As its name implies, it consists of a federation of thirteen *independent* scientific unions. They deal with the following branches of science: Astronomy, Geodesy and Geophysics, Pure and Applied Chemistry, Pure and Applied Physics, Biological Sciences, Mathematics, Radio-Science, Geography, Crystallography, Theoretical and Applied Mechanics, History and Philosophy of Science, Physiological Sciences, Biochemistry. Probably Geology will soon be added. The Federation has its Secretariat in Holland at the Paleis Noordeinde, The Hague.

I.C.S.U. has two chief objectives: to co-ordinate and facilitate the activities of the international scientific unions in the field of the natural sciences; and to act as a co-ordinating centre for the national organisation adhering to the Council. For this reason, I.C.S.U. has also national members, which are at present forty-eight in number. National committees are formed in countries adhering to the Unions: these represent each of the sciences; for instance, the Royal Society sponsors national committees for Chemistry, Physics, etc. Regarding the government of I.C.S.U., the Council meets in General Assembly every three years. During the interval, the business is carried on by the Executive Board and by a Bureau consisting of a President, two Vice-Presidents, Treasurer, Secretary-General, together with two ordinary members; all are elected by the General Assembly. It is interesting to note that five of the Secretaries-General have been British, so that the Royal Society has taken a very active interest in the initiation and maintenance of these international activities. Other societies, which have also been interested from 1919 have been the Académie des Sciences in France, and the National Academy of Sciences in the U.S.A.

The Unions organise International Congresses and also take care of committees concerned with nomenclature and other scientific matters concerned with their subject; and sometimes they find it useful to work as Joint Commissions with other Unions. The federation comes especially into play in the instances where special committees must be arranged for the exploration of matters requiring the expert attention of scientists from several different disciplines. These can only be arranged effectively by I.C.S.U., because it is an organisation of a majority of the working scientists in the world. Furthermore it is non-political: this means that activities are not limited by national boundaries. The criterion for admission is scientific status. In fact this is correct for science, because scientific activities are objective. To be accepted as fact, an experiment made in one part of the world must be repeatable in another part. If not, effort must be made to resolve the discrepancy. This is science, and no politics are concerned in such a confirmation of experimental fact.

At present there are four special committees: C.I.G. (concerned with the finish of the I.G.Y.), S.C.A.R. (Special Committee for Antarctic Research), C.O.S.P.A.R. (Committee on Space Research) and S.C.O.R. (Special Committee on Oceanic Research—aimed at the Indian Ocean). A few remarks will explain what some of these committees are doing. S.C.A.R. (President, Ing.-Gén. Laclavère; Secretary-General, Dr. G. de Q.

Robin) is busily concerned with research in the Antarctic, where scientists of many nations work together in harmony. The committee has been so successful that an international treaty is now taking shape, in which the signatory nations are agreeing to make no territorial claims in Antarctica for thirty-four years. S.C.A.R. is to be the official advisory committee. This is a fine instance of the way in which scientific effort can be a focus for a genuinely pacific movement. C.O.S.P.A.R. (President, Prof. H. C. van de Hulst), after some difficulties in obtaining a charter agreeable to all, has now settled down to a peaceful and co-operative study of outer space. It has already held two international symposia, one in Nice in January, 1961, the proceedings of which have been published, and another more recently in April, 1961, in Florence. It is to be hoped that these will focus the need for further world co-operation in this field. Finally, there is S.C.O.R. (President, Dr. G. F. Humphrey, Australia; Secretary-General, Dr. G. Böhnecke, Germany). The project in this case is to explore the Indian Ocean from every possible angle. Already some thirteen nations are taking part, and many ships. This project will not reach its maximum effort until 1962 or 1963. The Indian Ocean is little known, because the regular trade vessels only cross a small area of it. Knowledge of its currents and winds should help meteorology, and it is conjectured that the area may contain enormous numbers of fish which will be needed as a source of protein in view of the increasing population of the world. These special committees represent the most important new enterprises of I.C.S.U., because they can only be carried out properly by the whole federation of scientists working together.

In addition to these activities, I.C.S.U. also has responsibility for the Federation of Astronomical and Geophysical services and for world data centres. It is also concerned with abstracting work through the I.A.B. (I.C.S.U. Abstracting Board). The activities of I.C.S.U. are non-political, but the work of the Council brings it into relation with the scientific side of U.N.E.S.C.O. By agreement U.N.E.S.C.O. donates $175,000 a year, which is distributed by I.C.S.U. to the various Unions according to their needs. This sum is valuable, but not yet enough for the varied work of the Unions. In order that the work of I.C.S.U. and of U.N.E.S.C.O. may be co-ordinated where projects overlap, there has been established recently an I.C.S.U.-U.N.E.S.C.O. high-level committee for the mutual discussion of common problems.

In the modern scientific world, scientific co-operation is necessary and has come to stay. It is hoped shortly to extend the activities of I.C.S.U. towards certain biological projects, which also require global coverage. The Bureau for 1958–61, in addition to the President, has included the following: Past-President, Dr. L. V. Berkner (U.S.A.); Vice-Presidents, Prof. W. A. Engelhardt (Moscow) and Prof. A. Stoll (Basle); Treasurer, Col. E. Herbays (Brussels); Secretary-General, Prof. N. Herlofson (Stockholm); Members, Prof. S. Kaya (Tokyo), Ing.-Gén. G. R. Laclavère (Paris).

Wastes fixed in Glass

With the expansion of the atomic energy industry, much attention is being devoted all over the world to the development of effective, safe and inexpensive methods for the disposal of radioactive wastes.

Scientists and engineers of the Chemical Engineering Division, Atomic Energy Research Establishment of the U.K. Atomic Energy Authority at Harwell, are developing a method which is expected to simplify the storage of highly radioactive waste.

Laboratory work in the Chemistry and Chemical Engineering Divisions over the last few years has shown that it may be possible to store these materials by converting them into insoluble glass-like solids. Design of a pilot plant to handle 1000 curies of active waste per batch has now reached an advanced stage. The new unit will provide data on which the design of a full-scale plant might be based.

The glass is produced by making a slurry of silica and borax in a nitric acid solution of the concentrated liquid wastes, which, when evaporated to red heat, sinters and melts, and on cooling solidifies to a glass of chosen composition. A typical product might contain from 20 per cent to 30 per cent by weight, of waste oxides.

Experimental work has shown the properties of the glass remain substantially unchanged when samples are subjected to a radiation dose of 10^{9}

rads. This dose is comparable with the dose received by a glass incorporating high activity waste which has been stored for 500 years.

Atom

Nuclear Structure Research

It was announced during the summer that the Department of Scientific and Industrial Research would contribute over three-quarters of a million pounds (£750,932) towards a new nuclear physics research centre at Oxford University. This is the largest single grant ever made by the Department and will provide a particle accelerator of novel design with which Prof. Denys Wilkinson proposes to carry out an extended programme of long-term research on nuclear structure. In addition the National Institute for Research in Nuclear Science will carry out the design of part of the accelerator at a cost to the Institute of £200,000, which, with further aid from the University Grants Committee, brings the total government support for the project to approximately one million pounds.

This specially designed equipment will consist of an 8–10 MeV vertical Van de Graaff generator which will be coupled to a 12 MeV horizontal tandem Van de Graaff generator. With the energy that it will produce Prof. Wilkinson's Group will be able to study the structure of all nuclei. It will be the first of its type in the world.

Equipment of this size and cost must be regarded as a national asset and this accelerator, while primarily provided for Prof. Wilkinson's research programme, will, by agreement between D.S.I.R. and Oxford University, be available to other research workers.

Prof. Wilkinson is chiefly concerned with the way in which the elementary particles interact and form the tiny piece of complex machinery that is the nucleus. The nucleus is very rich in properties. It can exist in a multitude of excited states each of which must be studied by itself and in its relationship to its neighbours before nuclear structure is fully understood. This study must be carried out in a precisely-controlled manner using as probes beams of particles such as protons and alpha-particles whose energy is precisely defined, highly stabilised and accurately known.

The best way to generate such beams of particles, of other than rather low energy, is by the device known as the electrostatic generator or, after the inventor, the Van de Graaff generator. In this machine the electric charge is sprayed from fine points—small lightning conductors in reverse—on to an insulating rubber belt which transports the charge to the top of a hollow evacuated glass and metal tube where it is removed by the reverse process of jumping into a set of sharp spikes. The top of the tube therefore rises in voltage to a value which can be accurately controlled. At the top of the tube is a source of positive ions such as protons or deuterons which are accelerated down through the tube and at the bottom enter the laboratory for use.

The whole device is placed inside a pressure vessel containing gas at high pressure so that the high voltages involved do not provoke sparks. With such machines voltages as high as 8,000,000 can be attained. A recent ingenious modification of this machine is the tandem Van de Graaff generator in which negative ions—for example the ion formed by attaching an electron to a neutral hydrogen atom—are accelerated from ground potential up the tube into the machine. At the point of highest positive voltage they pass through a small amount of matter—gas or thin foil. This strips both the electrons away leaving the positive ion which is then further accelerated in the same straight line back to ground potential at the other end of the pressure vessel. In this way the high voltage is used twice over and so twice as much energy is transmitted to the ions as in a conventional machine. Many such tandem accelerators are now in operation up to effective voltages of 12,000,000 or so.

D.S.I.R.

Pure Fluid Amplifiers

An amplifier is a device that uses a small amount of energy to control or direct a larger amount. Vacuum tube amplifiers do not create any electrical energy; they simply control energy. A common vacuum tube is just a device that uses a small current to control a large current.

In electronics, one of the phenomena most responsible for automation is feedback. This simply means that part of the current sent to a motor or instrument to do work is returned to the deveic that is controlling the current flow. This is as though a job foreman (control device) had sent out a group of men to do a job and one of them kept returning to inform him of progress. Feedback, for

instance, operates between a thermostat and furnace. The furnace sends heat energy into a room to warm it. The thermostat continuously reports to the furnace on the progress of the warming job. It does this by collecting some of the heat energy sent to do work, converting it into electrical energy corresponding to the amount of work done (temperature) and sending it back to the furnace where it raises or lowers the flame as needed.

A *pure fluid amplifier* is nothing more than a block of metal, ceramic, or plastic with holes in it, but it makes possible 'electronics without electricity'. Such devices involve no moving parts; there is nothing to break or wear out; there is no need for replacement or maintenance; there are no chemicals that are sensitive to heat or fail to operate when they are cold; they are very much cheaper. These are some of the factors that will make pure fluid systems more reliable than many electronic systems and the present moving-part fluid-systems which are widely used in hydraulic and pneumatic systems.

Tomorrow's thermostat will be a PFA with a loop running from the living room back to the furnace. Air, which is already a fluid amplifier, will flow back through the fluid amplifier where it will deflect the incoming heating gas in accordance with the amount needed to raise or lower the room temperature. This simple flow of warm air—through a tube and some tunnels cut in a block of metal—is much less complicated than a thermostat and furnace-fan motor and the electrical circuit between them. An electrical circuit becomes even more complicated when feedback is used to control automatic lathes or to change the direction of a missile. However, the missile or lathe feedback circuit using PFAs will still be just small openings in a block of material.

The holes do not necessarily have to be little. They can carry some very strange 'fluids' indeed: pulverised coal and grain. Electrically automated coal loading and grain packaging operations are becoming commonplace. Soon the steady downward flow of fine coal or grain passing through properly arranged tunnels will push levers to shift rail cars or spread open bags and fill them with grain. Rivers, for example, are simply channels of moving fluids. PFA engineers see flood control in the future by means of giant pure fluid amplifiers cut as canals near river intersections; and tiny PFAs operated by the flow of river water and using the lever principle of amplifying forces will control flood gates in dams.

In the future—in home washing machines as well as in missile guidance systems, or automated industrial processes—streams of fluid and small solid blocks pierced by tiny tunnels will replace all the moving parts, vacuum tubes, and transistors, with a great gain in simplicity and service.

Science Horizons

North Borneo Expedition, 1961

Mount Kinabalu (13,455 ft.) is the highest peak between the Himalayas and the Snow Mountains of New Guinea and, though not a snow-mountain itself, it has an alpine flora relating these two parts of the world. It was first climbed in 1851 by Sir Hugh Low and has since attracted many botanists, zoologists and geologists. It is now known to have one of the richest floras of any mountain, but a great part of it remains to be explored.

To further the biological exploration of North Borneo, which will also assist the Government of North Borneo in its plans for the establishment of a national park on this famous mountain, the Royal Society set up in 1960 a committee under the chairmanship of Sir Joseph Hutchinson, C.M.G., F.R.S. This year, in co-operation with the Government of North Borneo, the Society is sending out a reconnaissance expedition under the leadership of Mr. E. J. H. Corner, F.R.S., to investigate the practically unexplored eastern side of the mountain where the forest extends down to the lowlands. In particular, the vegetation and soils will be studied as indicators of land which should be conserved within the boundaries of the national park. It is well-known that in these precipitous regions of high rainfall the clearing of luxuriant primary forest may lead to irreparable impoverishment of the soil with erosion and consequent silting and flooding of the rivers.

As soil scientist, Mr. G. P. Askew (Wye College, University of London) will accompany the expedition to work in conjunction with the Soils Division of the Department of Agriculture in North Borneo. Mr. Adam Stainton, who has taken part in the botanical exploration of Nepal, organised through the British Museum of Natural History, will assist in botanical and photographic work. The other

personnel has been drawn from Malaya, Sarawak and North Borneo with the intention of developing regional interest in the project. The Government of Singapore has made available from the staff of the Singapore Botanic Gardens the services of the botanist, Dr. Chew Wee Lek, and of two plant collectors, Md. Shah and Kadim b. Tassim. Much scientific work on the flora of Borneo has been done at these Gardens, the herbarium of which contains a very valuable set of Bornean plants. Md. Shah is the son of the late Haji Md. Nur, who contributed so much to the scientific work of the Gardens. General vertebrate zoology is in the charge of Prof. J. L. Harrison (Nanyang University), and Mr. Chin Phui Kong (Assistant Fisheries Officer, North Borneo). Mr. B. E. Smythies (Conservator of Forests, Sarawak), the author of the recently published book *Birds of Borneo*, will join the expedition as ornithologist. The Forest Department, North Borneo, is assisting in opening up the intended trail up the eastern shoulder of the mountain and across the so-called Pinosuk Plateau, which is a region of great scenic and biological interest, but apparently of little use for economic development. Various members of the Department will visit the expedition in its different stages.

It is intended to use a portable aluminium sheet hut as a base camp at an altitude of 5000 ft., whence local expeditions will be made with tents up the unexplored eastern approaches of the mountain. Since exact localisation will often be necessary a set of aerial photographs will be used in conjunction with the War Office and Air Ministry survey maps (1: 50,000).

Among the many objects of the expedition, special attention will be given to the soil conditions in the mossy forest at 5000–7000 ft. altitude and in the areas of ultrabasic rock, to the occurrence of the great parasitic flower *Rafflesia*, to the extraordinary variety of wild figs, and to the opportunity for obtaining photographs to illustrate Mr. Corner's Durian theory of tropical forests, Borneo being the centre of the remarkable genus of Durian trees.

Local arrangements have been made through the office of the Resident, West Coast Residency, North Borneo, and Messrs. Harrisons & Crosfield have undertaken to act as the expedition's agents in North Borneo. The botanical and zoological results will be co-ordinated by the staffs of the Royal Botanic Gardens, Kew, and the British Museum of Natural History respectively.

Science in Ceylon

The 16th Annual Session of the Ceylon Association for the Advancement of Science was held in Colombo in November 1960. The meeting was attended by about 500 members and a similar number of associates. It is interesting to note that, unlike the British Association, membership of the Ceylon Association is confined to scientists—non-scientists can attend a meeting as associates, but cannot become full members of the Association. It is perhaps a tribute to the scientific community in Ceylon that they can muster 500 members in a country where there is only one University and very little scientifically based industry.

The meeting was opened on the Thursday morning by His Excellency the Governor-General, Sir Oliver Goonetilleke, G.C.M.G., K.C.V.O., K.B.E., who besides welcoming the members and guests gave a wide ranging summary of scientific progress in Ceylon. He made particular reference to the improvements in medical science and the general increase in expectation of life. He was followed by the President, Dr. W. R. C. Paul, who took as the topic for his Presidential Address 'The Condition of Agriculture in Ceylon'. He dealt not only with the progress to date, but also highlighted many outstanding problems and gave some hint of ways in which they were being tackled.

The morning session concluded with a lecture by the chief guest, Prof. J. B. S. Haldane, F.R.S., who was very provoking on the subject of 'Biological Research with Simple Apparatus'. It was easy to agree that the apparatus required to collect the statistical information was simple enough, but before long the complicated apparatus of a digital computer will be needed to interpret the results.

After the general session on Thursday morning the meeting then proceeded to divide into its respective Sections for a series of Section Meetings. The organisation of the Ceylon Association differs fundamentally from that of the British Association: there are six Sections only and each Section covers a wide field. This means that in effect many of the lectures are aimed at a fairly comprehensive scientific audience and they do in fact become what are known in our Organisation as 'Joint Meetings'.

It can easily be realised that not only the members but the visitors would like to go to many more addresses than are possible in the time, but at least the Presidential Addresses of all the Sections are arranged when there are no other Section Meetings. All members can, therefore, attend at least each Sectional Presidential Address. It is perhaps unnecessary to give details of any of the individual Section addresses, but it is worth noting that there were three popular lectures given by three visiting scientists. Dr. Robert Blum, President of the Asia Confederation, lectured on 'The Role of University Research in Asia'; Prof. Haldane, F.R.S., on 'The Study of Human Heredity'; and Dr. I. J. Faulkner, the delegate from the British Association, on 'The Birth and Growth of a Chemical Industry'. Thus these three popular lectures covered the education of the scientist, the scientist as a research worker, and the scientist in industry—a very comprehensive coverage for a small Association.

In addition to the normal sessions, there were of course a number of other interesting things to do and see. The exhibition of over 300 scientific, medical and sociological periodicals which was arranged by the British Council in Ceylon was both comprehensive and very well attended. There were a series of showings of scientific films; the inevitable and particularly colourful afternoon tea party; and finally, on the Saturday night as a general wind up to the meeting, the Annual Dinner with a commendably short Toast List of commendably short and light-hearted speeches.

The Association now produces a Journal, *Vidya*, and volume No. 1 bears the date November 1960. In the words of the authors the object of the Journal is 'as a medium for the dissemination of science in a popular form. It is intended to reach a wide field, particularly schoolchildren whose knowledge and understanding of science will contribute to the development of the country in the future'. Certainly the first issue is an admirable document which will undoubtedly achieve its objective.

It would be unfair and unrepresentative of the country to confine these notes purely to the affairs of the Ceylon Association's Meeting. So much is going on of a scientific and general nature which would be of interest to the members of the British Association that some description of these activities is worth while. An Institute for Scientific and Industrial Research, centred in Colombo, has been set up by the Ceylon Government. Although the Institute is on a small scale it is well built, well appointed and located in a pleasant part of Colombo. The official pamphlet of the Institute states 'C.I.S.I.R. is not a government agency however. It is an autonomous non-profit corporate institution operated on business lines, with its own governing board, administration, and full-time staff of practical research engineers, scientists, craftsmen and assistants. It deals directly and confidentially with its clients, charging for its work on a fair and uniform basis to meet operating costs. Today private clients are its main support.' It is particularly interesting that it does not confine itself as might be expected to the physical and natural sciences, but is also prepared to enter the field of what might be called commercial sciences. It is prepared to carry out work on market research and management studies: it is prepared to advise on factory layout, costing systems, safety and hygiene and even industrial relations. It is developing a service of product testing which will enable both home and foreign customers to be sure of getting a product to a correct specification. It is equipped with the best technical library in Ceylon; a library which is used both by the University and the business community.

There are special research Institutes for the country's major industries—coconut, tea and rubber, and it is not possible to see all of them in a short visit. The Rubber Research Institute is situated about 50 miles south of Colombo in the rubber growing area. The Institute is equipped to deal with all aspects of rubber cultivation and is divided into sections which cover botany, plant breeding, plant pathology and soils. There is also a Chemistry Section which, besides dealing with specific chemical problems also runs a semi-technical rubber processing laboratory. This laboratory carries out processing tests both for the information of the Director and Staff of the Institute and also as a service to customers in investigating complaints and difficulties.

The cultivation of tea is, of course, a major industry and the tea estates cover a wide area of the hilly country in the centre of the island. Considerable research has been carried out on the tea plant itself, both in respect of plant breeding

cultivation and propagation. The tea planters themselves are still working on this and conducting further experiments on the most suitable fertilisers and the economic level of fertiliser application. Most impressive, however, is the sheer physical work that has had to be carried out over the last 70 years to convert this mountainous jungle into what can fairly be described as a 'tea garden'.

Finally, a word must be written about the new University Buildings. The Association Meetings were held in the buildings of the Science Faculties outside Colombo, but a new set of University Buildings has been erected at Peradeniya, just outside Kandy. The architects have made full use of the natural features even to retaining the original trees and have erected a set of residential and teaching buildings which would be a credit to any country in the world. This University campus is perhaps typical of the determination of the country to take its proper place amongst the nations of the world.

I. J. FAULKNER

Fire-extinguishing Powders

When finely divided, uranium, plutonium and (in particular) thorium metals are pyrophoric—they can ignite spontaneously in air.

In plants which process and work these metals—and any others with a similar property—turnings, drill chips, and swarf, present a handling and storage problem.

Sometimes, during processing and other operations, fires do occur. These must obviously be dealt with as speedily as possible because of the toxicity of plutonium or uranium oxides which could be produced and dispersed, but also because the materials are very valuable. And the method of extinction must also contain the burning material rather than spread it.

Metallurgists of the U.K. Atomic Energy Authority at Dounreay have produced a fire-extinguishing medium which is a eutectic mixture of dry powdered inorganic chlorides and/or fluorides inert towards the metal involved. The mixture is so chosen that its melting point is below the melting point of the burning metal. This produces two important effects:

1. Fusion of the powder takes place locally where it is in contact with the burning metal; a fused skin forms around the metal and this excludes the surrounding air from contact with it.
2. Absorption of latent heat by fusion of the powder exerts a cooling effect on the metal.

Very recently a powder of this type has been used in a test to compare its properties with those of other fire extinguishing powders where the ignited matter was light magnesium alloy for aircraft wheels. Again its performance was spectacularly successful while some of the other extinguishers in the test not only failed to extinguish the fire but, indeed, made it burn more fiercely.

The U.K. Atomic Energy Authority have so far granted licences for the manufacture of these fire extinguishing powders to John Kerr (Manchester) Ltd. Further information is available from the Patents Licensing Officer, U.K. Atomic Energy Authority, 11, Charles II Street, London, S.W.1.

Atom

War Gases help Research

In the study of blood diseases, radio-isotopes can give us information on two essential processes, the rate at which blood cells are being formed, and the life-span of these cells in the blood. Iron is a constituent of haemoglobin, the essential pigment of the red blood cells. For many years radioactive iron, Fe-59, has been used to measure the rate of formation of red blood cells in the bone marrow.

Red blood cells may be isolated from the blood of a patient, labelled by incubating them with a solution of sodium chromate containing radioactive chromium, Cr-51, and these labelled red cells may be injected back into the patient. By determining the quantity of labelled red cells in the blood after given intervals, the life span of the cells may be determined. Although chromium-51 has proved a reasonably satisfactory label for the red cells, until recently there was no label for the other important blood cells, namely, the white cells and the platelets.

During World War II, both adversaries developed, but fortunately never used, nerve gases. One of these is di-iso-propyl fluorophosphonate, or DFP. It is a colourless and odourless liquid, readily absorbed through the skin, and so dangerous that one drop may be enough to paralyse the respiratory system. It is sufficiently volatile to give a lethal concentration in air.

DFP acts by binding itself irreversibly to proteins. Its poisonous nature is due to the fact that it so binds itself to the enzyme cholinesterase, which is indispensible to all muscular activity. The 'blocking' of this enzyme system causes paralysis. This property of irreversible binding to protein can be put to good use in the labelling of blood cells.

If a tiny amount of DFP, labelled with radioactive phosphorus, P-32, is injected into a subject, the DFP rapidly and firmly attaches itself to all types of blood cells and so labels them. A sample of blood can be removed, the red cells, white cells and platelets separated, and the amount of activity in each fraction measured. By repeating the measurements at intervals, the life spans of these different cells can be determined.

The Radiochemical Centre of the U.K. Atomic Energy Authority, at Amersham is synthesising, DFP from radioactive phosphorus for use in medical clinics and laboratories all over the world: at present it is the only supplier of this valuable material.

Because it is so poisonous, the amount of DFP that can be injected without discomfort to a patient is extremely small, a fraction of a milligram. The problem that faced the Amersham chemists was to prepare this material at a high enough specific activity—over two hundred millicuries a gram. Another problem is the short useful life of the material: not only does phosphorus-32 decay with a half-life of 14 days, but the intense radiation causes breakdown of the DFP itself. It is therefore necessary to work to a strict time schedule, and to give workers in all parts of the world accurate advance information on the date of delivery of the product.

The production of each batch of DFP is run with the precision of a military operation. Customers are notified of the date of delivery one month ahead, and at the same time a silica ampoule containing a few milligrams of red phosphorus is placed in the highest flux of Harwell's DIDO research reactor. At the completion of irradiation, Amersham chemists have three days in which to synthesise the DFP, a difficult operation because of the small weight of material, its toxicity, and its intense radioactivity. The material must be assayed for radioactivity, subjected to rigorous analytical examination for purity, and despatched in accordance with the pre-arranged schedules.

DFP is not the only war gas that is finding peaceful uses. Mustard gas also is a valuable biological reagent; indeed, closely related chemicals are used in the treatment of many forms of cancer. Among the many biological entities to which mustard gas will attach itself are the polynucleotide chains which are fundamentally involved in the process of cell division. To obtain the maximum information on the points at which mustard gas becomes attached, and the subsequent breaking of the chains, mustard gas containing radioactive sulphur, S-35, is employed. This labelled mustard gas is regularly synthesised by the Amersham team of chemists.

Atom

NEW HEADQUARTERS FOR THE ASSOCIATION

The Association moves to new premises at the end of August: its new office address from September 1, 1961, onwards will be No. 3, Sanctuary Buildings, Gt. Smith Street, London, S.W.1

THE HUMANITY OF MAN*

By Sir WILFRID LE GROS CLARK, F.R.S. *President of the Association*

In his presidential address to the British Association for the Advancement of Science at Bristol over sixty years ago, Sir William Crookes remarked that while formerly the President unrolled to the meeting a panorama of the year's progress in physical and biological sciences, now he usually restricted himself to speculations connected with his own work, or dealt with questions which for the time were uppermost. If I have both these objectives in mind in my address it is not out of sheer presumption, but because my own studies have for many years been related to man as he was in the past and man as he now is, and these studies naturally compel considerations of his potentialities for dealing with problems of the immediate future. Just as many individuals rightly seek to take stock of their personal achievements and failures at the end of each year and aim to correct their defects by resolving to carry out certain plans for the New Year, so I think it is now most necessary, because of the dangerous uncertainties looming ahead, to take stock of the species *Homo sapiens* whose evolution has culminated in mankind today. I believe it is our duty as scientists to insist that this is a matter of quite extraordinary urgency and to make it apparent as far and wide as possible. For, let us not deceive ourselves, the frightening question is now beginning to present itself whether the civilisation which mankind has slowly and laboriously built up over a period of many thousands of years can avoid disastrous dissolution as the result of uncontrollable (or, at any rate, uncontrolled) struggles for political power or economic superiority, and, indeed, whether the human species can avoid at least partial extinction by the misapplication of its own ingenuity. This is not to be taken as a melodramatic statement—it expresses a truth which is quite evident to anyone who cares to read the signs of the times.

Naturally, in the course of a short address I can only make a very brief reference to some few aspects of my subject by attempting a rapid review of how we came to be and how we are constituted in our physical and psychological adaptability to cope with the changing environment in which we find ourselves today. The first part of this task is the easier, for the chronicle of the prehistoric story of human evolution and its bridge across the 'protohistoric' into the historical record now provides a reasonably close-graded developmental sequence whose interpretation offers little difficulty so far as its main features are concerned. When the British Association met at Norwich in 1868 the objective fossil evidence for human evolution was practically non-existent, and when, three years later, Darwin published his *Descent of Man*, he had to rely for his thesis of man's relationship to lower animals almost entirely on the indirect evidence of comparative anatomy, embryology, the persistent relics of vestigial structures in the human body, and so forth. Today the situation is very different, following the discovery of the fossilised remains of early hominids showing just those transitional characters which Darwin had postulated for 'missing links' between the simian and the human levels of evolutionary development.

Some of the earliest known of these precursors of modern man were the small-brained creatures, technically called the Australopithecines, which inhabited South Africa and East Africa as far back as the geological period of the Early Pleistocene, that is to say, half a million to a million years ago (or, according to the latest information, perhaps of even greater antiquity). These have commonly

* Presidential Address delivered to the British Association at Norwich on August 30, 1961.

been referred to as 'hominids' rather than 'humans' because, although they are certainly early representatives of the zoological family Hominidae (of which we ourselves comprise the terminal and only surviving species) we do not know whether they had developed all those mental attributes which together are usually associated in common parlance with the designation 'human'. We know a good deal about their anatomy from the large quantities of their skeletal remains which have been found in a reasonably good state of preservation. The evidence is complete that they were erect bipedal creatures with a hominid type of pelvis, they had a dentition quite similar to that of modern and extinct types of man except for the large size of the grinding teeth, and many features of their skull show a remarkable approximation to their human successors. But their brain was quite small—in fact, hardly exceeding in size the brain of a gorilla. The first discovery of these primitive hominids naturally gave rise to much controversy, mainly for the reason that some authorities had become imbued with the conception (at one time widely held) that the initial stages in the emergence of the line of hominid evolution, and its segregation from the ape line, must have been conditioned by a marked increase in the brain volume. We now know that this conception was wrong—the expansion of the brain came much later. The acquisition of a bipedal mode of progression, that is, standing, walking and running on two feet, was presumably related to climatic changes resulting in a deforestation of the areas inhabited by ancestral precursors of arboreal habitat. This, of course, is a somewhat speculative explanation, but it remains clear enough that the liberation of the arms and hands from their climbing functions was of quite fundamental importance in permitting the development of a manipulative skill which came to be expressed in the ability to use and fabricate implements of stone and other material. From the evidence of recent discoveries in Tanganyika it seems a reasonable inference that, as had already been suspected from excavations in South Africa, some of the Australopithecines in spite of the small size of their brain were indeed tool-makers, and they also hunted game for food. Now, all these discoveries have been tremendously exciting for students of human evolution, not only because they provide the direct evidence for Darwin's thesis of man's descent, but because they also offer some of the earliest indications of the habits of life and the mentality that characterised human ancestry.

Man has been defined, in contrast with lower mammals, as the tool-making animal; if this definition is accepted, then the terms 'man' and 'human' can perhaps be applied to the small-brained Australopithecines. It may be argued that the definition is not altogether valid because, for example, tame chimpanzees, presented with the problem of reaching food beyond their grasp, have been observed on a rare occasion to construct a tool by fitting two sticks together so as to make an implement long enough to reach a banana. But, apart from the fact that we have no evidence that apes in the wild state, that is, without some general training, are capable of inventing tools, one of the essential differences from the specifically human type of tool-making is that the ape can only construct an implement for a purpose which is immediately presenting itself; human beings, on the other hand, can construct tools in preparation for future contingencies, and this implies a capacity for mental imagery and foresight far beyond the level of any sub-human creature. We do not know just how far the Early Pleistocene hominids were capable of planning ahead in this way, but many of their tools, though of crude construction, not only show a certain uniformity of pattern which indicates a collective application by different individuals of a common technique in their manufacture, but there is also evidence that they were capable of making tools of several kinds as well as shaping pieces of bone to form pointed implements, suggesting a capacity for modifying the design of their implements for different specific purposes. This implies that they had already developed what can be termed a 'cultural tradition', at any rate in incipient form. The other important inference from recent excavations is that they were not only food gatherers but hunters of game, and it has been pointed out that, if we can assume that the dietary habits of the modern apes were also typical of our ape-like arboreal ancestors, this indicates a rather radical evolutionary change from predominantly vegetarian to carnivorous habits. The geological evidence makes it clear that the Australopithecines occupied a terrain of the savannah or veldt type to which they could only adapt themselves by developing such habits in association with their

erect bipedalism. Moreover, it has been argued that the adoption of a meat diet must have had far-reaching effects on their social organisation. For one thing, the initiation of hunting habits stimulated the need for implements of some sort that could be used for the killing and cutting up of game, and it also demanded co-operation within organised groups of hunters who had no natural weapons of attack or defence such as the powerful sharp canines which many other representatives of the order Primates possess. As Dr. Oakley has observed 'bipedalism is initially disadvantageous biologically unless there is some compensating factor—in the case of the hominids this was the ability to use tools and wield them while moving'. Clearly, the Early Pleistocene hominids must have been particularly vulnerable in the open—they could only have survived in the form of hunting communities equipped with weapons of some sort. It may also be inferred that their ability to co-operate in hunting depended on a capacity for mutual planning in order to take concerted action for the benefit of the community as a whole.

The temporal successors of the Australopithecines (no doubt with some overlap in time in different parts of the world) are represented by an extinct type of man known as *Pithecanthropus* whose remains have been found mainly in the Far East and who lived during the early part of the Middle Pleistocene, two or three hundred thousand years ago. They were more advanced in anatomical structure, with limbs of quite modern type, and with a brain of larger size though on the average only about two-thirds the volume of our own today. But they evidently lived in well-organised and co-operative communities, showed considerable skill in fashioning stone implements, were capable hunters, and even knew the use of fire for domestic purposes. There is now some evidence that populations of the *Pithecanthropus* type may have extended from the Far East into the African continent and perhaps elsewhere, but they were soon followed by (or were transformed by evolutionary modification into) more progressive types of later Middle Pleistocene age which show a closer approach to *Homo sapiens*. Indeed, so similar were some of these later types to the modern types that such differences as there are can only be demonstrated by elaborate statistical methods. Lastly, by the beginning of the Late Pleistocene many parts of the Old World were populated by men who, as far as can be inferred from their skeletal remains, were no different from mankind today. Estimates based on radio-active carbon techniques have shown that *Homo sapiens* of modern type was already living in the Old World about fifty thousand years ago, and indirect evidence makes it probable that the antiquity of our species extends back to a time level of the order of a hundred thousand years. The Palaeolithic populations of Aurignacian times, who occupied Western Europe about thirty thousand years ago, had developed a social organisation of considerable complexity and were also responsible for some fine examples of cave paintings and sculptures.

By about 7000 B.C. the Neolithic Age had blossomed forth in the Near East with the discovery of the domestication and breeding of animals for food and other purposes, and the cultivation of edible plants which provided an important element of their diet. The agricultural surplus thus made available permitted the growth of settled and relatively stable communities in which the essential factor of the co-operation of individuals for the benefit of the community as a whole became much more obtrusive. Metal artefacts came into use in the Eastern Mediterranean with the discovery of copper and bronze for tool-making about 3000 B.C., and the technique of smelting iron was invented in Asia Minor soon after about 1200 B.C. (though the regular use of this technique did not spread into Western Europe until 500 B.C.).

A brief narrative of the major features of any line of evolution, such as I have just attempted, has the serious disadvantage of gross over-simplification, and tends to give an illusory impression that the evolutionary changes have been the result of a steady progress in which the evolving populations played a more or less passive role. But it is important to recognise that human evolution has by no means been a history of uninterrupted, unidirectional, progress. For example, there were long periods of cultural stagnation in the Early and Middle Pleistocene during which it seems evident that primitive man must have been compelled to concentrate all his energies simply on keeping himself and his family alive in day-to-day existence, contending against almost overwhelming difficulties in the face of a harsh and unfriendly

environment, and equipped with only the crudest weapons for his defence and with the most limited means of providing himself with sustenance and shelter. We have only to think of the extreme climatic vicissitudes of the Ice Age to realise that the very survival of Palaeolithic man in Europe and elsewhere could hardly at that time have been prognosticated with any assurance.

I have noted that probably the main factor which determined the initial segregation of the hominid line of evolution was the adoption of an erect bipedal posture in adaptation to an open terrain, and that the expansion of the brain which is so outstanding a character of *Homo sapiens* came later. It now appears from the fossil record that the hominid brain did not begin to enlarge significantly before the beginning of the Pleistocene, but from the Middle Pleistocene onwards it expanded at a most remarkable speed—greatly exceeding the rate of evolutionary change which has so far been recorded in any anatomical character in lower animals. Now, with very few exceptions a progressive enlargement of the brain has characterised all groups of mammals since their early ancestors appeared more than fifty million years ago, but in the Primates the expansion began earlier, proceeded more rapidly, and ultimately advanced much farther. The expansion also contrasted in the particular regions of the brain which were predominantly affected. Let me emphasise this difference in the following way. The forebrain (comprising what is termed the cerebrum) includes certain basal elements technically called the hypothalamus, amygdala and so forth, to which we may conveniently (but rather loosely) refer as the 'basal brain', and a larger mass covered by a convoluted layer of grey matter which we may call—also rather loosely—the 'cortical brain'. These two components are functionally interconnected, but while experimental and clinical observations have established that the 'basal brain' presides over our internal economy in the sense that it is fundamentally concerned with the regulation of essential bodily processes such as digestive, cardio-vascular and general metabolic functions, hormonal secretions, reproductive rhythms, etc., and also contains neural mechanisms underlying emotional reactions and their associated drives, the 'cortical brain' is concerned rather with the more discriminative aspects of sensory experience and motor control. It is these discriminative faculties which enable us to respond to the changing circumstances of our environment in a manner which is the most advantageous not merely to us as individuals but to the community to which we belong. To a variable degree in different mammals the more primitive functions of the 'basal brain' can be modified by the 'cortical brain' on the basis of the information which the latter is continually receiving (or has received in the past). In lower mammals this information permits a more accurate regulation of the instinctive activities which to a large extent dominate their behaviour. But in the higher Primates, particularly in man, the 'cortical brain' has come to assume an increasing control of the 'basal brain'. The conception at one time current in psychology that mental experience can be separated into the rather sharply contrasted categories termed 'cognitive' and 'affective' has long since been recognised as misleading, for intellectual and emotional factors are so closely interlocked in any form of behaviour that they cannot be dissociated—even arbitrarily. Intellectual processes are only capable of full expression if they are activated and energised by the driving power of emotional processes which come to be associated with feelings of aesthetic satisfaction. Undoubtedly one of the outstanding distinctions of the human brain is the enhancement of the interconnections between the 'basal brain' and the 'cortical brain', to the extent that emotional drives may be made much more subservient to the ideational processes which are based on cortical activity. The latter can now, if needs be, hold these drives in check, or exploit them by directing them into channels serving the co-operative requirements of human society. Of course, many of us do not use this machinery of the brain as efficiently as we might do; but the point is that, in purely neurological terms, the machinery does exist to be made use of.

The expansion of the brain in hominid evolution involved all the so-called association areas of the 'cortical brain', but the enlargement of the frontal lobes—which give *Homo sapiens* the high forehead that is so distinctive of our species—is perhaps the most striking feature. Although the functions of the frontal lobes are highly complex, latterly we have learnt a good deal about this region of the brain from laboratory and clinical studies. It may now be accepted that the frontal lobes do not

comprise the essential basis for intelligence *per se*, for even after they have been extensively destroyed by injury the intelligence of the patient may in some cases show no appreciable deterioration so far as can be determined by the usual tests. On the other hand they are certainly of importance for making full use of intellectual potentialities under normal circumstances, because it is largely through them that the nervous mechanisms of emotional and instinctive drives which reside in the 'basal brain' are, so to speak, harnessed to the higher conceptual functions of the cortex. The loss of these controlling influences of the frontal lobes is demonstrated very clearly by interruption of their connections with the 'basal brain' following brain injuries or leucotomy operations. In many such cases the patient is no longer able to adapt his behaviour to the social needs and conventions to which he normally conforms. He becomes impulsive, irresponsible, inconsiderate in his attitude towards his fellows, and unable to sustain intellectual activities in planning far ahead. In other words, he tends to become antisocial in his behaviour. Observations of this sort give a clue to the factors which initiated the remarkable development of the brain in *Homo sapiens*, for it now seems pretty certain that it was the development of the distinctively human type of social organisation, depending in the first instance on the use of tools and weapons in co-operative activities for foraging and hunting for food and for the protection of family groups, which demanded an accelerated development of those parts of the brain whereby emotional and instinctive impulses can be more effectively subordinated to the good of the community as a whole. The progressive elaboration of culture sequences which followed must also have depended on the inventive capacity of gifted individuals whose imaginative ability derived from a greater complexity of the cerebral cortex, and it is easy to understand that such individuals would confer a high survival value on the particular community in which they happened to appear. The rapidity of the evolutionary expansion of the brain during the Pleistocene is an example of what has been termed 'explosive evolution', and it emphasises the extraordinary severity of the selective pressure which determined the initial appearance on this earth of our own species.

Another factor, doubtless related also to the requirements of a tool-making and organised hunting community, which conditioned the rapid expansion of the hominid brain must have been the development of the extrinsic type of symbolisation which we call language. There are, of course, other means of communication between individuals besides language—such as facial expression, gestures, the utterance of sounds which signal emotions of fear, pleasure, aggression and so forth. So far as sounds are concerned, Dr. Schultz has remarked that 'the simian Primates are by far the noisiest of all mammals' but 'as soon as the early hominids had ventured into open spaces, had begun to use and even make tools and had co-operated in hunting, the total variety of all means of expression needed additions which could only come from sounds'. It is indeed difficult to suppose that even the primitive and small-brained Australopithecines could have developed the inventiveness required for a tool-making culture or could have collaborated in planned hunting expeditions if they had no verbal means (however elementary) for communicating instructions and for the social transmission from one generation to another of acquired skills. At any rate, the ability to interchange ideas by a system of verbal symbolisation must certainly have been a prerequisite for the elaboration of the more advanced and complex cultures of the Middle and Late Pleistocene, and the progressive perfection of such a system also provided the essential basis for the further development of the co-operative element which is so dominant a feature of the social organisation of human communities. For verbal symbolisation permits individuals to interchange information not only about things which immediately present themselves to the senses, but about events of the past and possible contingencies of the future; more than this, it enables one individual to obtain a closer indication of the innermost feelings of his fellows and thus identify himself much more intimately with them psychologically. Correlated with these developments is the germination and progressive florescence of self-awareness, that is, the recognition of the self as distinct from the environment and from other selves, which, in time, expresses itself in what may be termed reflective consciousness. And it is this sense of separateness, of course, which finally leads us on to the seemingly endless problem of how far the

apparent realities of the external world reflect ultimate realities. Such a degree of self-awareness is the very basis of the consciously directed co-operative and altruistic element in human behaviour which is one of the main components of what may be termed the humanity of man.

If I had the time at my disposal I would like to elaborate the thesis that the emergence of the biological species *Homo sapiens* has been the resultant of selective pressures directly dependent on the invention and development of cultural organisations of increasing complexity. Thus the initial evolution of the human type of brain has been correlated with modifications in the differential growth rates of the cranial skeleton, the reduction of the jaws and teeth, the perfecting of the locomotor apparatus, and the ultimate refinement of the structure of the hand for manual dexterity, and so forth. Even more important is the correlated extension of the period of immaturity during which the growing child remains dependent on the adult members of the community, for this not only makes possible the full post-natal development of the large and complicated brain, it also provides the opportunity for educating the individual to adapt himself to the intricate interrelationships of human society. It may be said, indeed, that if man (in the broadest sense) invented culture, it was culture which invented *Homo sapiens*. Such a conception is not new—it has been simmering in the minds of anthropologists over the last few years, but it now needs to be more fully recognised.

Well, here we are today, the modern representatives of *Homo sapiens*, and up to now, after several hundred thousand years of rigorous striving and struggle in the face of adversities which at times must have appeared all but insuperable, our evolutionary success in the biological sense is sufficiently demonstrated by the fact that almost 3000 million individual specimens of our species are now scattered over the greater part of the world living in widely different physical and social environments. This itself is expressive of one of the outstanding features of our species—a broad and plastic adaptability rather than a narrow adaptedness to one particular set of conditions. But our biological adaptability needs to be constantly supplemented by deliberate and conscious efforts to adapt ourselves to local circumstances as they arise. In the exploration and exploitation of territories of climatic extremes, for example, or in trying to cope with the artificial conditions which we are continually creating for ourselves in different fields of human activity, we seek to find ways of adapting ourselves to new local environments or (if that is impossible) of adapting the local environment to ourselves. So far as physical and biological environments are concerned we have some reason to be satisfied with ourselves in that we have hitherto met with considerable success by making use of all the resources of the physical and biological sciences and of the technological developments which have been derived from them, by the development of more effective methods of pest control and protection against disease, and also by intensive studies of the physiological and psychological factors underlying the adaptational potentialities of the human body. In the last several years much progress has been made in laboratory and field investigations of problems of climatic adaptation in man and animals, and closely related to this is the development of a field of research which has come to be termed Ergonomics, that is, the study in the widest context of man in relation to his working environment. I need hardly emphasise the relevance of Ergonomics to industry, for this is now widely recognised for its importance in the rational design of machinery and in the control of the immediate climatic environment, whether natural or artificial, in which tasks need to be carried out.

But while we can feel some assurance of ultimate success in such material problems (so long as adequate funds and facilities are made available for their investigation by scientific methods), the sociological environment to which mankind as a whole needs to adapt himself presents a much more formidable problem. I have expressed the view that consciously directed co-operativeness has been the major factor which determined the evolutionary origin of *Homo sapiens* as a newly emergent species and the gradual development of the peculiarly human form of integrated society, and in this connection I am reminded of the words of John Stuart Mill 125 years ago that 'there is not a more accurate test of the progress of civilisation than the progress of the power of co-operation'. In the past this element of co-operativeness has led to the progressive assimilation of smaller groups

into larger groups of increasingly complex social structure—at first families into assemblages of families, these into wider communities based on close kinship, into clans and tribes, and later into the still larger economic and political units represented by states, federations of states, and the nations of the world. Naturally, I do not suggest that this process of assimilation has been a matter of even, steady, advancement—like the analogous process of biological evolution it has been chequered with long intervals of stagnation and periodic regressions. But there has been demonstrably a broad historical trend in the direction of a progressive unification of mankind. In some cases this has come about by mutual agreement for the furtherance of common interests, but it must be admitted that it has not unusually been the result of conflict between opposing groups ending in the subsequent mergence of the vanquished into the social and economic structure of the victor. In so far as this process of unification has been to the ultimate benefit of the community as a whole by achieving a higher level of co-operation which, for example, permits a more centralised organisation of all the means of production, more efficient control over local fluctuations in food supply, more comprehensive planning of large-scale projects of irrigation and transport, more economical division of labour by specialists of various kinds and so forth, it can be regarded as a major factor determining sociological progress. But the basic difficulty with the larger groupings of human society, as it seems to me, is that, with increasing population pressure, the altruistic sentiments which in the course of a long evolutionary history have become ingrained in the mentality of the *individual* are too apt to be suppressed by the narrow interests of each particular *group*. The larger the group the less control has the private individual in directing his innate impulses along channels which are ethically satisfying to him personally, for his attitudes and opinions come to be more and more directed for him by all the subtleties of propaganda developed in a complex society. At any rate, we now have to face the seemingly paradoxical fact that the larger the units of co-operation in social communities the greater the tendency for their segregation into populations opposed to each other by conflicting economic and ideological interests. Thus the historical process of unification has tended to slow up and ultimately threatens to come to a halt. If it has sometimes been the outcome of conflict in the past this can no longer be envisaged as practicable in the future, for a major conflict involving the nations of the world today must lead to a degree of destruction that would render precarious the very existence of mankind. We seek to escape from this impasse and we ask ourselves whether it is even feasible to hope for a final unification of mankind as a whole. At the moment few would be optimistic enough to give a reassuring answer to this question, and no doubt many would regard it as too unreal and idealistic to be worth consideration.

Yet one thing seems clear—an essential prerequisite for any attempt at further unification for the good of mankind as a whole is the ability to give full expression to the impulse for co-operation which is so characteristic a feature of the humanity of man, and this can only be made possible by opportunities for free intercourse and the free interchange of ideas among the population of the world.

In the promotion of such an ideal I believe that science has a vitally important part to play, for fundamental science (the pursuit of knowledge for its own sake), together with technological science (in its application of this knowledge for the benefit of mankind as a whole), may surely be regarded as one of the culminating expressions of that co-operativeness on which depended the genesis of the human form of society in the distant past. I do not mean to imply that science among all other intellectual disciplines has a complete prerogative in this respect, but I do suggest that it is in a particularly favourable position to effect the closest contacts between peoples who are otherwise divided by political and other interests. For one thing, scientists of all countries feel impelled to retain and develop harmonious relations simply because they realise that the very advancement of their subject depends on a thorough acquaintance with work going on elsewhere—the progress of science is essentially the result of co-operative human effort. They may not all speak the same tongue, but they can and do speak with a common idiom and use a common terminology, and communication of knowledge and ideas from one individual to another can be more precise and certain in scientific phraseology just because the

latter aims to be more carefully defined than phraseology of colloquial language. One may say, further, that there is a universality in the logic of scientific method which permits an intimacy of understanding hardly possible in fields of learning where there are fundamental conflicts of opinion derived from preconceived convictions and beliefs based on unverifiable evidence, and not amenable to scientific methods of enquiry by the rigorous test of repeated observation and experiment.

In so far as science by its very nature imposes on the scientist and the scientifically-minded an ethical code of profound respect for objective truth it is to be regarded as intrinsically a self-regulating process. For any statements or judgements based on current scientific research must be open to continuous scrutiny in the light of subsequent research, with the freely admitted possibility that they may from time to time need to be revised or rejected. Co-operativeness is an integral element in this process of self-regulation and thereby contributes to the promotion of a sense of tolerance and intellectual humility. Finally, I would assert that the quintessence of the scientific mentality is to be found in a willingness to communicate and discuss new advances in knowledge with completely open-minded freedom, uninhibited by any attempt at secrecy for partisan or sectional interests of any kind whatsoever; it cannot be too strongly emphasised that secretiveness is the very antithesis of the spirit of free enquiry implicit in the scientific method. From the purely practical point of view, also, secretiveness acts as a serious brake on the advancement of science because the latter can only proceed actively through the unrestricted interchange and interpenetration of ideas among those engaged on problems of common interest.

In the past, the free intercourse between scholars of different countries by travel or correspondence was first demonstrated in the early days of the Renaissance Period when it was a common custom for scientists to undertake arduous journeys from this country to the great medieval universities of the Continent to acquaint themselves with current advances in scientific knowledge. Even during the Napoleonic Wars and the American Civil War, as Sir Gavin de Beer has recorded in his book *The Sciences were never at War*, scientists were able to travel unmolested through enemy territories. Unhappily, the situation has become very different in our own time, but I think it may be said that scientists in general all over the world are still striving to maintain a sense of unity in the face of circumstances which often appear very frustrating. For many years, of course, they have been in the habit of arranging international congresses in a variety of subjects, with a membership freely open to all those competent to contribute papers or join in discussions, and anyone who has participated in such congresses will have experienced the real sense of fellowship between man and man which inevitably develops in the course of probing problems of common interest.

Limited international scientific associations date back to the middle of the last century, but at the instigation of our Royal Society an association of a fully international character, the International Association of Academies, met for the first time in 1900. This was followed after the First World War by the formation of an International Research Council which met in Brussels in 1919. But unfortunately it came to assume a political character because certain nations were deliberately excluded from membership, and even when they were ultimately admitted in 1926 the stigma of political bias still remained. Finally, the International Research Council was dissolved in 1931, being replaced by the International Council of Scientific Unions which aimed to be a truly international federation with the separate Unions retaining their individual autonomy. At present there are thirteen Unions including all the major physical and biological sciences, as well as the Union of the History and Philosophy of Science. From time to time the Council has formed Special Committees or Joint Commissions—for example, a Special Committee for the International Geophysical Year, another on Oceanic Research, and another on Antarctic Research. In all its multifarious activities, the International Scientific Unions have contributed much to international understanding, and I suppose the International Geophysical Year of 1957–8 was perhaps one of the most outstanding examples of the intimate collaboration between scientists of many nations for the benefit of mankind in general; it illustrates particularly well the important point that associations which are *wholly* international are essential for achieving full international unity. International scientific associations which are exclusive, in the sense that they admit membership of some nations and not others, can only engender suspicion and

disharmony. It has even been suggested that the very term 'international' is psychologically objectionable because it presupposes and perpetuates the idea of the existence of separate national units. Certainly, in so far as international organisations are taken to represent governments upon which they depend for financial support (however tenuous this link may be), an undesirable element of political bias tends to be introduced.

Undoubtedly one of the most important developments in science during recent years is the multiplication of international congresses, colloquies, symposia and so forth, and I take this to be an expression of the urgent need felt by the scientifically-minded to maintain and extend still further contacts in a world which threatens to become disrupted by the conflict of national interests. Even more significant, I think, is an evident tendency to replace the term 'international' by more comprehensive and all-embracing titles. Thus we have the Food and Agriculture Organisation, the World Meteorological Association, the World Federation for Mental Health, the World Federation for Neurology and so forth. But apart from such specific organisations, individual scientific societies are themselves tending to become more international in scope and more cosmopolitan in their membership. For example, the Ergonomics Research Society, because of the importance of its work in so many fields of economic importance, attracts membership from individual scientists all over the world. One more point I should like to make here is the desirability more and more of supplementing or replacing 'national' research institutions by 'regional' research institutions for the study of problems of common interest in different geographical areas—in this connection I think of current organisations such as the Arid Zone Commission, the Pacific Science Association, centres of research on locust control, and so forth. It hardly needs to be stressed that the immediate and obvious advantages which accrue from regional research in the relatively undeveloped countries are more likely than anything else to remove any possible feelings of suspicion or distrust towards the more developed countries from which assistance is received. If the membership of the staff of regional institutions were unconditionally open to competent scientists of any community whose welfare depends on the results of its research projects, this would do much to engender an atmosphere of concord and to dissipate any tendency towards national rivalry which may exist. In short, we need to aim for international co-operation, and not international competition, in scientific research—the full freedom of the one, and not the restrictive reticence of the other.

The British Association can with some reason claim a good share in the promotion of international amity through the medium of science, for it has always provided an open forum for the free discussion of contemporary problems which confront mankind not only in this country but all over the world. Its membership is a completely open membership, its Council is represented during each year at meetings of various scientific bodies in countries abroad, and for many years it has received as its guests at the Annual Meeting distinguished scientists from overseas. More than this, by its lecture services, young people's programmes, international youth science conferences, area committees, 'science fairs' and so forth, it has made increasing and impressive contributions towards the development of more widespread scientific education. Incidentally, I think it needs to be recognised, also, that the most important objective of the Annual Meetings of the British Association lies not so much in the mere recording and recounting year by year of new scientific discoveries, but rather in making clear their probable impact on the day to day life of individual citizens and the communities to which they belong, and, more important still, in demonstrating and explaining the principles and methods of scientific enquiry by which these discoveries have been made with the inferential corollary that the same principles and methods can also be applied, with a considerable assurance of success, to other outstanding problems of a similar nature. In more general terms, our task is to inculcate as widely as possible that spirit of freedom in scientific enquiry which gives full expression to the deep-rooted altruism which, as I have already tried to emphasise, is an essential attribute of the humanity of man and which, I believe, can do more than anything else to preserve and intensify the feeling of harmony among all peoples of the world. But we need to press ahead in our efforts with the utmost vigour, for the dangers which now threaten the unity of mankind are formidable indeed.

And time is getting very short.

THE ECONOMIC USE OF BRAINS

By Prof. C. F. CARTER *Stanley Jevons Professor of Political Economy, The University of Manchester*

Two years ago, at York, Professor Jewkes in his presidential address examined the alleged shortage of scientists and technologists. Mine is a vaguer subject. It is, I believe, the general experience of those who recruit staff that there is a shortage of all the higher forms of ability; that it is exceedingly difficult to find, not only good scientists, but able managers, effective higher civil servants, and gifted members of the professions. Many scientists believe that within this general shortage the deficiency of able scientists is especially acute, because our educational system has a bias towards arts subjects. I see no evidence whatever that this bias now exists, and indeed it could be argued that the specialised study of science and technology is in danger of attracting an undue proportion of able minds. The degree of bias which existed in the last half-century still has some effect on the stock of working scientists, but I believe nevertheless that at the higher levels of ability it is more significant to examine the general shortage rather than the specialist deficiencies.

The importance of this general shortage is increasingly recognised. This country is heavily populated, and not well endowed with natural resources other than its people; its ability to maintain a high standard of living and to earn the necessary large sums by exporting to a highly competitive world depends above all on the effective use of brains. As technology becomes more complex, this resource of brain-power and ability tends to become more important relative to other natural resources. Furthermore, because ideas and methods of organisation and working are capable of being copied, a special importance attaches to those of the highest ability, ingenuity and inventiveness who set an example to others. Such people have a special importance in dealing with the complex problems of change; indeed, one can say that at many points in the economy and the social system it is the supply of first-rate ability which determines the speed of change, all other shortages being of secondary importance.

My subject is thus a scarce and important factor of production, which in the freer parts of the labour market often commands a high price. My contention is that we have given surprisingly little thought to the nature and proper use of this factor, and that there is considerable need for further study and research. Our neglect is partly a result of our general vagueness about the nature and contribution of the factor 'labour'; and I see that another aspect of the matter has recently been discussed by Theodore W. Schultz, in his presidential address to the American Economic Association.[1]

I would like to draw your attention first of all to the difficulty of defining what we mean when in common speech we talk of an 'able man'. Some may wish to argue that there is no such thing as 'ability' in general, but only ability in relation to a particular task; and obviously it is true that a man can be a brilliant salesman but quite unsuited to be a production manager. Yet we do not call a man 'able' if his only skill is the perfect performance of a very narrow task. The shortage of the higher forms of ability is a shortage of men who are capable of dealing with *new* and *unexpected* tasks within a certain range, and who are not confined within too narrow a specialisation. We are looking for an intelligence which is capable of analysing a new situation and reacting to it in a sensible way.

Something more is required, however, than a developed intelligence. This creates difficulties for our colleagues in other disciplines who seek an escape from vagueness in definitions of the types

of ability which will enable them to be identified and measured. People can be intelligent but ineffective, and the possible causes of ineffectiveness are numerous and difficult to classify. We are all familiar with the problem of the man who, after a promising start, reaches a 'ceiling' and goes no further, or the man who takes refuge from thought in a multitude of business; or the man who, though a pleasant colleague in a position of small responsibility, turns out when given larger responsibilities to have unsuspected faults of character which lessen his effectiveness. Occasionally we are reminded of how little we know about reserves of ability when some accident of death brings to a high position a man who had never been considered suitable to bear responsibility, and he turns out to be notably successful. In fact, we make serious errors in both directions in our judgements about how intelligent men will react to the stress of responsibility.

I have no doubt that scientific selection procedure can reduce these errors, but it is my impression that personnel selection at the highest levels has a long way to go before it can claim to be very scientific. The efforts to define and measure ability tend to lose relation with the reality which (by its fruits) we recognise and which we are trying to define. In consequence those who recruit staff at the highest levels take refuge in imprecise generalities about 'leadership' and 'character'. Mr. Peter Drucker puts as the first requirement of a sound recruitment policy for management an 'uncompromising emphasis on integrity of character'.[2] Samuel Smiles found, in the biographies of the great, abundant evidence of the importance of 'energetic individualism', perseverance, hard work and self-help. These are qualities difficult to reduce to a statistical measure, but none the less a significant part of our overall impression of high ability. Perhaps a convenient brief way of describing that impression is to call it 'effective intelligence'.

Of the waste of this resource, Marshall wrote: 'There is no extravagance more prejudicial to the growth of national wealth than that wasteful negligence which allows genius that happens to be born of lowly parentage to expend itself in lowly work. No change would conduce so much to a rapid increase of material wealth as an improvement in our schools, and especially those of the middle grades, provided it be combined with an extensive system of scholarships, which will enable the clever son of a working man to rise gradually from school to school till he has the best theoretical and practical education which the age can give'.[3] He thought indeed that 'it is probable that the percentage of children of the working classes who are endowed with natural abilities of the highest order is not so great as that of the children of people who have attained or have inherited a higher position in society. But since the manual labour classes are four or five times as numerous as all other classes put together, it is not unlikely that more than half the best natural genius that is born into the country belongs to them; and of this a great part is fruitless for want of opportunity'.[3]

This may be described as the 'water supply' theory of ability—that there is an ample supply, provided it is conserved. It may be regarded as supported by a number of studies, such as the report on *Early Leaving*,[4] which have shown the continuing connection between a long and successful educational career and high social class of the parents. It is still true, for instance, that the probability that a boy will go to a university is very much greater if he comes from a professional, rather than a 'working class', family; and it is quite clear that this difference cannot be attributed entirely to money and influence, but represents a real advantage in attainment for those who have an appropriate social background.

The conclusion usually erected on this foundation is that, if we had more and better education, the supply of able people would be increased. This conclusion does not appear to follow from the evidence. Assuming that only a small part of the observed differences in attainment can be explained by differences in intelligence at an early age, what the evidence suggests is that a large number of children would have developed further if they had been born into a higher social class; in other words, that we might be able to alter the supply of ability if we could alter the social structure or environment in some relevant way. It is not certain that an improvement in educational provision will produce this relevant alteration, still less that it is the best or only way to produce it. As far as I have been able to discover, we do not yet know which of the many interrelated characteristics of a poor social environment are most important in restricting the

development of a child. Proceeding by guesswork, however, it seems reasonable to suppose that a child experiences increasing difficulty and sense of separation, the more he departs from the attitudes and values of his parents; and that in consequence an increase in the supply of ability is to be expected only slowly, and only if we can assume that attitudes and values will change so as to give a higher place of honour to developed and effective intelligence. Some people consider that a significant change of this kind is going on at the present time.

Even if we accept this optimistic view, however, we have to consider the possibility that increased numbers will be found for the middle ranges of ability, rather than for the high levels which are the subject of this paper. Professor Williams and I drew attention in *Industry and Technical Progress* to the fact that in the early 1950's first-class honours degrees were being awarded to about 25 per cent more people than before the war, while second-class honours degrees had increased by 120 per cent. We commented that 'if university examinations are accepted as consistent evidence of quality, (this) strongly suggests that a further scraping of the barrel will not yield many more first-class minds'.[5] This small piece of evidence is perhaps misleading, for a first-class honours degree is neither necessary nor sufficient as evidence of high ability; but it does not seem unreasonable to suppose that among the attributes of outstanding ability is an unusual power to rise above the limitations of social class, and that the British educational system before the war may have been far more efficient at recognising and assisting the really able boy than it was at developing the best qualities of the mediocre.

I conclude, therefore, that we need further evidence before it will be safe to suppose that there is plenty of high ability available, at present running to waste, and easily conserved. A more cautious view was expressed by Sir Robert Wood: 'We are not going to get a great deal more first-rate intellectual butter, we are going to have to spread it over more bread, and make do with a deal of margarine'.[6] Therefore it is appropriate to look at what we do with the butter which we at present have. But in doing so we at once come up against a singularly puzzling problem. What is the best use of an able man's time?

Mr. Peter Drucker refers to a study made by Professor Carlson and his associates of the way in which twelve leading Swedish industrialists use their time. 'They found that not one of the twelve executives was ever able to work uninterruptedly more than twenty minutes at a time—at least not in the office. Only at home was there some chance of concentration. And the only one of the twelve who did not make important, long-range decisions 'off the cuff', and sandwiched in between unimportant but long telephone calls and 'crisis' problems, was the executive who worked at home every morning for an hour and a half before coming to the office'.[7] This inability to concentrate is a common complaint of business and professional men, senior civil servants, and university professors. Many senior scientists complain that they are diverted from their true work to perform routine tasks, and that if only they had a larger staff of technicians they could be more productive. Able men in almost all walks of life complain of the monstrous burden of committees. Those who represent an institution in some public capacity complain of the time which they must waste in attending social gatherings. If one takes all these complaints at their face value, the labour of those of high ability must be grossly misused.

Some economic writings have regarded 'labour' as a self-evident concept, not needing to be defined, or have treated it as the curse which rested on Adam, an activity of inherent disutility. 'Labour', says Jevons, 'is any painful exertion of mind or body undergone partly or wholly with a view to future good.'[8] Marshall, however, with his usual common-sense, omitted the word 'painful', and proposed that 'labour' should simply be an exertion 'undergone partly or wholly with a view to some good other than the pleasure derived directly from the work'.[9] This is clearly a necessary change for my present purpose; the intellectual labour of an able man, so far from being painful, may be the greatest source of pleasure in his life. But there has been little disposition to explore the nature of this 'labour', which is a much more complicated matter than digging a ditch. At one time he will be adding to his store of facts and ideas by study; at another, evaluating the work of his subordinates; at another, drawing on his experience to make a decision; at another, exerting himself to win friends and influence people, to counsel, to encourage or to

admonish. By what means do we find out if he is being properly used?

The business efficiency expert would, I suspect, give the simple answer that the able man should not be doing work within the powers of those of less ability. The economist would say much the same in a more sophisticated way, and talk about possible marginal substitutions of cheaper factors of production. Such answers, however, show little appreciation of the complex nature of intellectual effort, and of the importance to an able man of a combination or alternation of easy or routine tasks with periods of more strenuous activity. A brilliant scientist does not want to spend his days sitting in a corner of his laboratory, engaged in pure thought, while his assistants perform the experiments under his direction. The grumbles about inadequate help from technicians can in fact be matched by complaints from technicians and industrial staff in laboratories that scientists insist on doing work which ought to be the responsibility of junior staff.

It is, in any case, almost inevitable that the work-load of an able man should contain a large proportion of quite simple tasks, which do not need his ability. He is often required as a decision-maker, and his ability is employed because there is little or no check on his decisions. It is therefore important that the best qualities of mind and experience should be available to deal with difficult, controversial and complicated matters; but it is seldom possible to filter out all lesser problems, and deal with them at a lower level in the organisation. One aspect of the right use of ability is certainly to design information systems so that these lesser problems 'solve themselves' and do not take the time of those whose scarce qualities can be better used; but this filtering process is inevitably very imperfect. Schemes of organisation tend to reserve certain duties of decision to those at the top, and these duties have to be exercised even on unimportant matters.

More generally, there is always liable to be a lack of agreement between function and ability. A large engineering firm employs a first-rate mathematician because it will occasionally have an urgent need for creative mathematical talent of a high order, but the function which it will assign to the mathematician will not be confined to the solution of *difficult* problems. The able man is in fact often used like the engine of a car, capable in emergency of propelling the vehicle at ninety miles per hour but seldom used above sixty. The disparity between peak requirements and normal use is perhaps less in the case of self-employed creative artists, but even they must have long periods of less creative activity.

Clearly the idea of 'proper use' of ability involves a balance between peak requirements and normal use, and it may be surmised that if one tried to drive a first-rate man continuously at 'motorway speeds' he would become unhappy, like an overheated engine. But we know very little about the right balance of use. Thus it is not surprising that Professor Williams and I found in our industrial studies that very little attention had been given to the 'science of using scientists productively', for this is a field of productivity studies in which there is the greatest difficulty in defining either the output or the input. More generally, it seems to me that in all forms of work which employ high ability, there is need for a great deal more study of the conditions which favour effective work. No doubt the difficulty of analysing these conditions, and of defining 'effective work', will rob such study of the elegance of precise results; but I consider that there are worth-while principles to be discovered, and reforms to be made. I cannot believe, for instance, that the load of paper which piles up on the desks of senior civil servants represents an optimal combination of the easy and the important, designed to maximise the output of speedy and wise advice and decision.

It is, of course, true that men of high ability are often in positions in which they create their own conditions of work, and it might be thought that they would act so as to maximise their own happiness, and that (being contented) they would be effective. Observation suggests, however, that able men may give too much freedom to the lust for power or for control, and that thereby they give themselves an excessive work-load of detailed regulation, or spread their activities too widely to be effective. The economic use of brains may involve protecting a man from the self-imposed wastage of his talents, as well as giving him freedom to use them to the full. Some large industrial companies have recognised the importance of this, and take some care to preserve the senior executive from attempting too much.

I now turn to another aspect of the use of ability, namely the way in which it is distributed between different occupations. This distribution is created by two factors: the ways in which men of ability have chosen their initial occupations, at various dates during the last half-century, and the transfers between occupations which have taken place since. Of these factors, the first seems much the most important. Outstanding ability is no doubt more versatile than mediocrity, but it remains very difficult in this country for people to make a change of occupation after the age of twenty-five. Senior business executives sometimes make a complete change of industry, though this may involve little change of occupation; yet it is still a matter for surprise (and for some even a matter for resentment) if a manager moves from (say) the chemical industry to the railways. The movement of scientists from research to administration is a significant form of mobility, while the armed forces, by having an early age for retirement, enforce some valuable change; and war, that great mixer, has given to this generation unusual opportunities for a change of career. Peacetime efforts to promote mobility (e.g. between the universities and the civil service) seem, however, to have only limited success. Such matters as prescribed arrangements for professional training and inflexible pension schemes combine with the natural inertia of organisations to limit opportunities for change of occupation. It is the impression of many observers that these opportunities are greater in the United States; the reasons for this would be an interesting matter for sociological research.

If there were no mobility between occupations, then the possibility of changing the distribution of ability would be limited to the annual 'turnover' of two or three per cent of the working population by recruitment, retirement and death. This means that quite large changes in the initial choice of occupation by those of high ability would produce only a slow change in the whole distribution of ability. Furthermore, the visible effects of this change may be delayed; thus, if a group of brilliant young men is brought into an industry short of talent, it may still be ten or fifteen years before they rise to positions of responsibility from which they can influence events. These obvious facts are sometimes forgotten by those who question the value we receive from industry's recently increased power to attract talent.

Of the initial choice of occupation, there is no doubt much more that we could learn. The choice of occupations available to an intelligent boy or girl is considerably narrowed by his choice of specialisation at school—a choice which in Britain is made more definitely and earlier than in most other countries. A little is known about the way in which this choice is made: it seems to be necessarily ill-informed, both in regard to the potentialities of the boy or girl, and in regard to the advantages or pleasures to be found in the occupations to which the specialisation will lead. The choice of subject at a university is often allowed to follow naturally from the specialisation at school. Thus most people of ability, at the age of leaving school or university, find themselves with a choice limited by happenings which have only a tenuous relation either to the national interest or to their personal advantage.

In the selection then made, we know that matters of fashion and social prestige play a considerable part. An industry or occupation which is considered old-fashioned, fixed in its ways, dull or declining finds it exceedingly difficult to attract able minds—although an infusion of fresh talent may be just what is needed to give it an achievement which will cancel its bad reputation. An industry or occupation which is new, growing and glamorous, much discussed in the newspapers and on the television, may attract talent beyond what is justified either by its needs or its future prospects. These shifts of popularity are to some extent natural and inevitable, but to some extent also mysterious—they are related to the scale of social prestige which we mostly take for granted, but can neither explain nor justify. It is clear that *initial* salary is not a decisive influence in selection, for the teaching profession has remained unattractive despite having relatively generous initial salaries; probably a vague and ill-informed estimate of earning prospects over working life is more important. The importance of security and of regular progression towards higher responsibilities is at one time considerable, at another less; in the post-war years the general security of full employment has probably made young entrants less concerned about the particular security offered (for instance) by the civil service.

It follows from this that, though an occupation can do something to attract ability by offering good salary prospects, the most important thing to be done is to make its 'public image' more attractive. There is need for more research on the reasons for the shifts in popularity. If I am right in laying such stress on the sociological factors, there can be little relation (except by accident) between changes in the distribution of ability and the national need. Indeed, in a community which has no strong sense of national objectives, it may be exceedingly difficult to divert lively and able minds from the occupations which are fashionable and relatively well supplied with ability to those which most need its help.

If we identify 'high ability', unjustifiably, with the possession of a first-class honours degree, it is possible to give the actual choices of career made somewhat more precision. Thus the P.E.P. survey of graduate employment[10] (relating to a sample of graduates of 1950) shows the following results for the 'first paid career employment' of first-class honours graduates:

	Percentage for first-class honours graduates	*Percentage for all graduates in sample*
Civil Service	4	3
Civil Service (scientific)	11	6
Local government service	2	4
Teaching (school)	9	23
Universities	18	4
Commerce	2	8
Industry	30	29
Armed Services	1	2
The Churches	1	4
Law	2	4
Other occupations	7	7
No career employment by 1954	13	6
	100	100

The figures are interesting as showing the large appetite of the universities for their more brilliant young; the poor showing of the traditional professions for the sons of gentlemen, the Army, the Church and the Law; and the strong attraction (at that time) of the scientific civil service. 17 per cent of first-class honours graduates in Arts went into school teaching, 7 per cent of science graduates, and 1 per cent of technology graduates; no less than 32 per cent of first-class arts graduates from Oxford or Cambridge went into university employment, and only 6 per cent into industry. (It must be remembered that many industrialists have a definite aversion to first-class honours as evidence of ability.) The figures also suggest some questions. For instance, the demand from the universities is rapidly increasing, and, even if one could take a more realistic statistical definition of 'high ability', it is clear that the universities absorb a substantial part of it. Is this large share of scarce resources properly used? If one regards a university simply as a seminary for the young, it is difficult to answer 'yes' to this question; but of course the universities are also the source of a large part of the national effort in fundamental research, and this raises quite different problems of the right use of manpower in relation (for instance) to scarce scientific equipment.

But the P.E.P. and similar surveys do not give any full answer to the important questions. How is high ability distributed between modern and traditional industries, between expanding and declining industries, between large and small firms, or between different parts of the country? How much is attracted to nationalised industries, and which parts of the public service are starved of ability? What trends can be seen in the demands of the various industries and services? However imperfect the definitions of ability which must be used, there is need for more research on these matters, for we shall continue to find a need for discussing the maldistribution of this scarce resource. Thus, Professor Thwaites of Southampton, having pointed out in his inaugural lecture the danger 'that mathematical education as it has been known in Britain this century could come to an end within 20 years', said that 'the demands for mathematicians made by professions other than teaching must be voluntarily and severely contracted. There was a great opportunity for industry to think out afresh and to justify its minimum requirements for graduate mathematicians over the next few years.'[11] This is an important matter of public policy, and we have an imperfect basis of fact on which to decide it, for (though something is known about the distributoin of mathematicians by employment) we do not know much about how mathematicians use their skill in their various jobs, nor about the future needs of different industries for mathematicians.

So far, I have argued that we need to know more about factors affecting the supply of high ability, more about its best use within a particular occupation, and more about the way in which its distribution between occupations is determined. We should not, in my view, allow the inevitable vagueness of these matters to prevent us from approaching them as scientifically as we can, and giving them as much care as we should take over the right use of an expensive machine. In conclusion, I wish to propose a fourth subject of research: are there economies of scale in the use of high ability?

This is a matter which can be argued both ways. On the one hand, it may appear that a man capable of making right decisions about a million pounds can make right decisions about ten million; that a scientist's ability to make new discoveries will not be reduced (and may be increased) if his product has a large market rather than a small; that the number of positions of leadership to be filled does not expand in proportion to the size of an organisation or of a country. On the other hand, a large organisation may frustrate ability by its own complexity. The proportion of time taken up by liaison grows until it promises to exclude creative work; the size of organisation delays decisions and multiplies the occasions of frustration. No doubt each argument can be illustrated in a particular case, but it is a matter of some importance to know which is of most frequent application.

Thus, if we suppose (in the absence of any convincing evidence to the contrary) that the innate qualities required for high ability appear equally often in all nations, and if we suppose that there *is* an advantage in large scale, then those large countries whose social systems do not frustrate ability will have an advantage over small nations. Dr. B. K. Blount makes the point, in relation to the supply of scientists, as follows:

> As far as the production of genius is concerned, there is no master race. If this is so, then the number of geniuses turning up in any country will be directly proportional to its population. That this has not until now always appeared to be the case must be ascribed to differences of opportunity. A genius is often unorthodox, and in many times and places unorthodoxy has been a dangerous characteristic and has not been conducive to survival. . . . But with the possibilities of conscious planning, we can ensure that our geniuses are brought into the educational system; and we can, if we will, guide them in the direction of science, or at least put no obstacle in their way. . . . When China has ordered her affairs, as she is now doing with all speed, we can expect her to produce ten times as many scientists of world repute as we can. [12]

This opens up interesting reflections about the balance of economic power. But Dr. Blount further concludes that 'if we are to use our manpower to best advantage we shall have to guide almost all our best men in the direction of science and technology'; and he envisages 'other activities requiring ability' as being largely manned by middle-aged and elderly scientists who have lost the desire for further technical work. Is this the right use of scarce ability? Unless we recognise this to be an economic problem, deserving of at least as much attention and research as any other problem in the best use of scarce resources, we shall not reach a sound judgement about it.

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THE NEED FOR ADVANCEMENT OF MARINE SCIENCE

By Dr. G. E. R. DEACON, C.B.E., F.R.S. *Director, National Institute of Oceanography*

It is difficult to urge the importance of doing more without risk of appearing to minimise the serviceableness of what has been done already. Sailors are keen and accurate observers, quick to learn and skilled in application. The high standard of their instruments, sailing directions, charts, astronomical tables and other navigational aids is clear evidence of their activity and enterprise. They have also studied the sea itself. As long ago as 1854 Admiral Smyth, who became Vice-President of the Royal Society, emphasised that as well as higher practice in mechanical navigation their advances included more accurate information respecting the phenomena of winds and currents. A year later Admiral Fitzroy, first Director of the Meteorological Department of the Board of Trade, said that the great increase of nautical knowledge had not only much shortened sea passages but had rendered them more secure.

Advances in mechanical navigation have gone on just as fast since then, but the study of the sea itself has made surprisingly little progress. Some aspects such as tides and marine biology have been actively pursued but attempts to apply basic knowledge of other things to problems in meteorology, navigation, coastal engineering and the fisheries are still hindered by a remarkable lack of understanding, especially of the physics of the sea. Most industries soon learnt to profit from systematic study directed towards fuller knowledge and understanding of the basic materials and processes with which they were concerned, but contrary to the hopes and expectations expressed by Admiral Smyth science has not spread as rapidly over the sea as over the land. The annual cost of delay and damage to ships from waves, and of protecting coasts and maintaining harbours is almost astronomical, but it has been accepted with little question. It has needed disasters, like the sinking of the *Titanic*, failure of important fisheries, and intensive flooding of highly populated coastal areas, to launch marine research. The last war, the biggest catastrophe of all, has done more than everything else to establish oceanography as an exact science.

Lord Kelvin, one of the pioneers of tide prediction, remarked that when you can measure what you are speaking about, and express it in numbers, you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind. A devotee of Art might question this, but it is a golden rule for Science. Sailors had made pretty good estimates of the height of waves, and scientists engaged in sea-plane research had begun to develop apparatus to measure them, but it was not till near the end of the last war that we could make continuous recordings on anything like the scale needed for basic research. Early writers knew how waves often came in high and low groups so that the tenth or seventh, or something like that, is always the highest, and Stokes, who made important contributions to the theoretical study of waves in the middle of last century, showed that the alternating high and low groups must, like the beating of sound waves, be the result of interference between a number of wave trains, with waves of different length and speed, but it was not till 1944 that Admiralty scientists made the first spectrum analysis of sea waves.

The oceans have always been as full of water waves as the atmosphere now is of radio waves. The great storms send out long waves that can be received half way round the world and there are less powerful sources wherever the surface is disturbed and wherever a wave breaks. The first

series of wave analyses in 1945 showed that the waves in a storm area behave as a mixture of trains of waves of all wavelengths, from the shortest ripples up to long, low, oscillations with wavelengths (the distance between successive crests) as much as three to four thousand feet. As the wind dies down, or the waves run out of the storm area, these different wavelengths travel independently, each with a velocity proportional to the square root of the wavelength, as we should expect from simple theory. The result is a procession of waves which lengthens as it goes: the longest waves getting farther and farther ahead of the shorter. Each successive waveband appears in the changing spectrum at the receiving station, and, assuming they all come from the same place, and knowing the rate of travel of each band, we can calculate how far they have travelled. Having satisfied ourselves that this gave the right answer for a number of well-defined North Atlantic storms, we can be confident in our interpretation when a very slow displacement of the waveband across the spectrum shows that recorders near Land's End have detected swell a few inches high from the neighbourhood of Cape Horn. On the coast of California swell has been traced back to storms south of New Zealand, and even to the neighbourhood of Kerguelen in the Indian Ocean, to which there is an open great-circle path south of Australia.

These rather exciting discoveries have a practical side. The ability to separate wavebands from different storms from each other and from the spectrum of local waves near the recording station allows more systematic study of how the distribution of energy and the height and length of the waves depend on the strength of the wind and on the time and distance over which it blows. This has led to marked improvement of wave forecasts from meteorological charts and forecasts for a variety of purposes. Forecasts prepared as long as four days ahead are beginning to be used to plan optimum routes for ships crossing the North Atlantic and North Pacific Oceans, with the idea of reducing delay and damage from waves. Experiments with 1000 ships of the U.S. Military Sea Transport Service showed that the ships, using a plan prepared just before the ship sails, and perhaps adjusted once or twice during the voyage, could on an average save 14 hours on a crossing of the North Atlantic Ocean. Such a saving of time saves a lot of money and the avoidance of the worst wave conditions also means a good deal to the comfort of the passengers and the safety of cargo.

Recent advances in the statistical treatment of the sea surface are a most remarkable scientific achievement. With the help of relatively few measurements from a wave record it is now possible to describe the very irregular sea surface in such a precise manner as to allow remarkably accurate predictions of the probability of given wave heights, slopes and accelerations. The calculation of statistical expressions for the motions of ships, and the probabilities of given accelerations and stresses, is a relatively straightforward extension of this work; and the precise description of the sea surface, which is not the sort of thing that sailors or engineers would have done, has brought research on the design and sea-keeping qualities of ships to the threshold of new developments. Oceanographers, making a systematic study of the sea, have also developed equipment by which a ship can make satisfactory records of the profile of the waves through which she is travelling, and if the ship can be stopped—a quite revolutionary idea—they can use wave-recording buoys which will give the directional properties of the prevailing wave pattern.

The study of waves in shallow water is just as promising. There is a wide-open field for research, particularly for theoretical workers, on the transport of water and momentum towards beaches on which waves are breaking. We already begin to understand why under certain conditions of wave height and beach slope there can be an appreciable rise in water level close to the beach, and under other conditions a fall. The relevant studies have an important bearing on research into 'range action', the troublesome oscillation which puts many harbours on open coasts almost out of action from time to time. They will also increase our knowledge and understanding of dangerous currents in the surf which are a continual hazard to bathers, and of the general problem of coast erosion. This sort of work might be regarded as hydraulic engineering, but if oceanographers do not go up the beaches and estuaries to high-water mark at the same time as engineers work down them to low-water mark, the shallow water

problems, which are on the whole more difficult than those of deep water, will not be solved.

The action of sea waves does not stop at the coast. Careful theoretical work has shown that the interference of similar waves travelling in opposite directions can produce variations in mean pressure on the sea bed sufficient to generate ground waves. The wave interference can be caused by a proportion of oncoming wave energy being reflected back from a coast, or by the interaction of waves from different quadrants of a moving atmospheric depression, and by the meeting of swell from two quite different generating areas. The pressure variations on the sea bed are not large, probably only a few inches of water, but they take place over relatively large areas and it has been shown that they can put enough energy into the sea floor to account for the microseismic ground oscillations that form the main background to seismological records at nearly all observatories. The existence of such a mechanism has been clearly demonstrated by simultaneous analyses of wave and microseism spectra during well-defined wave conditions. By analysing and correlating records of microseisms and taking due account of the effects of refraction and of the changes in the character of the ground waves as they travel hundreds and thousands of miles from the generating area we can already use them to get useful information about the sea waves which are producing them. The results ought to be some use to seismology. They give a new understanding of the noise background, and the observable changes in the character of the ground waves as they travel between ocean and continent and through mountain ranges may well provide material for studies of crustal structure.

So far we have only used ordinary sea waves as an example of the growing interest of marine research. Promising studies of long waves (including seismic and storm surges), changes in sea level and the circulation of water in the oceans were mentioned in the account of the I.G.Y. read at Cardiff (*see Advancement of Science*, XVII, *No. 69, Jan. 1961*), and the excitement and promise of other aspects is just as great. For example, there is still much to be done about tidal oscillations. We know quite a lot about the tides in the oceans, but could get a much better picture if the distribution of phase and amplitude were known for a better coverage of points over the oceans, not just round the edges where all the harbour gauges are situated, and where the ocean tides are considerably modified by passage over the continental shelf and local resonances. To get a representative series of measurements from the deep ocean appears a very formidable task to oceanographers, but there can be no doubt that it is, technically, quite a trivial problem compared with what is done when adequate resources are available as in aeronautics and space research. There are still plenty of questions of immediate practical importance in shallow water and estuaries. We need better information about meteorological disturbances of the tides and abont the interaction between tides and storm surges. There is also need to know more about the earth tides which are large enough to have an effect on the ocean tides.

Until recently geology stopped at the edges of the continents and almost nothing was known of the sea floor, but in the past ten years there has been rapid development in methods and instruments to study its problems and important new theories have been put forward about the forces at work. Improved echo sounders allow contours to be drawn at fathom intervals on the abyssal plains that fringe the continents. Such new detail, together with information about the distribution of sand, silt and marine deposits, obtained by taking vertical cores, leaves little doubt that the plains have been produced by the filling in of all depressions, by sediment-laden currents originating along the continental shelf and spreading over the plains for distances of several hundred, or even a thousand, miles. The plains have a small but definite gradient of the order of 1 in 500 to 1 in 5000 that decreases away from the source of the sediments. The continental slopes lead down to the plains like steep shore lines to the surface of a lake. The mid-ocean ridges emerge just as sharply from the opposite sides, and the foothills and other prominent features that have not been submerged stand up from the flat sediment like islands. There is evidence from the breaking and burying of submarine cables that silt slumps or 'turbidity currents' can go down the submerged continental slopes at the speed of express trains. Many doubts have been expressed as to whether this is possible under water, but it now appears that there are no serious objections from a hydrodynamical point of view. There is apparently so little mixing with the

neighbouring water that the decay of the current is slow, and it is reasonable to believe that it can travel the large distance suggested by the observations. No other process can explain the remarkable flatness of the plains. The fact that the sediment covers a rugged basement is demonstrated by varying magnetic and gravity profiles across the plain, as well as by underlying rock profiles obtained by seismic soundings through the sediments. New methods of piercing the sediments are being developed using high-energy low-frequency sound sources, and a new field of exploration is opening before us. There are deep-sea channels 2 to 3 miles down which look as though they have been scoured by rivers, and deep clefts in the mid-ocean ridge which should tell us something of the history of the earth. Some of the bottom deposits, notably manganese nodules, offer some possibility of early exploitation. One of the most remarkable things is the apparent ease with which a ship operating in water 2 miles deep has bored and obtained continuous samples through 500 ft. of sediment and 50 ft. of the underlying rock.

Biology is the most absorbing and best established branch of marine science. It is pursued in most Universities; special laboratories are devoted to it all over the world, and it is the basic study of all organised fishery research. Yet there is still much to be done, specially in the open ocean. University interest in the oceans has declined in favour of more accessible fields and more manageable problems, the sort of thing that will fit in best with University routine and the organisation of Ph.D. courses. The trend was first towards ecological studies of shallow water, and more recently to biochemical and physiological studies. These are very necessary for ultimate understanding of what goes on in the sea, but they will not by themselves build up a basic picture of life in the oceans.

Oceanography serves fisheries science in much the same way as the biology, geology, physics and chemistry done on land serve agriculture and forestry. But the ocean biologists, geologists, physicists and chemists are spread much thinner over the water. Experiments in transplanting and establishing alien varieties have only just begun in the ocean (almost as true of scientists as of fish) and there is as yet no prospect of breeding more vigorous hybrids, the sort of thing that is the mainstay of agriculture. We do nothing about the weeds and pests. The animals that compete with or parasitise and prey on the fish grow along with them unchallenged. Much is being done to help fishermen find new grounds and to lessen the effects of intensive fishing, but the effort devoted to the work is small in comparison with the promise of a larger, sustained, effort. Statistics show that we derive 99 per cent of our food from the land and 1 per cent from the sea, and fuller exploitation of both oceanic and coastal fisheries is urgent in view of rising populations and standards of living.

At present relatively few of our best graduates are attracted to oceanography. This is understandable because the total effort is small and facilities and career prospects correspondingly limited. The long-term nature and other difficulties of the subject tend to make it unattractive to University scientists. The difficulties of working far from land and getting enough money are serious enough. Another drawback is that oceanography, in common with other environmental sciences, has been, or has been regarded as, a science of observation rather than experiment. The usual procedure has been for expeditions to return with a vast amount of data which have usually been examined, listed and plotted in orderly fashion so that new and remarkable features have been distinguished and described, and their explanation attempted, but this has taken many years and has usually exhausted the enthusiasm of those who promoted the expedition and almost always the funds provided for it. It has then been too difficult to send another expedition to look for corroborative evidence and further reasoning has had to wait till another venture, often with a different purpose, has happened to make observations in a fortunate conjuncture of circumstances. By such delay the keenness of enquiry is blunted. Progress is slower and the periods of dormancy longer than those suffered by sciences that can appeal to experiment. The marine biological saga about the migration of the freshwater eel is a case in point. By analysis of hundreds of plankton samples from many localities in the North Altantic Ocean J. Schmidt traced the geographic distribution of smaller and smaller eel larvae till he eventually found the eggs themselves in an area 600 miles south-east of Bermuda. How the European freshwater eels navigate back to this

part of the ocean to breed is one of the greatest mysteries of nature, and now D. W. Tucker has suggested that they might not manage it, and that instead the European rivers may be fed by descendants of American eels which breed in the same place and live a good deal nearer to it. He maintains that it is rather unlikely that European and American larvae could become segregated as they both drift away from the breeding ground in the same current. Questions like this cannot be answered by manageable laboratory experiments. Even if biochemists eventually make eels lay eggs at home, a sea-going research campaign is needed and there is no marine biological or fisheries laboratory that can hazard everything on such a key problem however telling it might be. Oceanographers value theoretical work and experiment as much as observation. There are so many places to explore and so many things to look for that guidance from theory is even more important in nature than in the laboratory. The difficulty is to design and carry out experiments to test the theory. Forbes's mistaken idea that nothing lived below 300 fathoms was followed by an active search that set deep-sea biology on its feet. Other ideas not sufficiently put to the test might discourage progress for a century. Oceanographers are also conscious that theory and experiment must go hand in hand, and the biologist with the physicist, and the physicist with the engineer.

Perhaps they are not bold enough in their approach, and a bit too much weighed down by day-to-day problems to have enough energy to race ahead like the laboratory sciences and like some of the newer aspects of their own science. The Editor of the *Quarterly Review*, writing of environmental sciences as long ago as 1840, said, 'We may wait it is true and consign to centuries to come, the toils, the glories, and the hopes of science, or we may rely on an easy effort distributed over length of years for the accomplishment of much that vigorous exertion might now effect'. . . . 'There are secrets of nature we would fain see revealed while we yet live in the flesh—resources hidden in her fertile bosom for the well-being of man upon earth we would fain see opened up for the use of the generation to which we belong'. . . . 'Our demands are not merely for a slight and casual sprinkling to refresh and invigorate an ornamental or luxurious project, but for a copious, steady, and well directed stream to call forth from a soil ready to yield it an ample healthful and remunerating harvest.'

We are still content to speculate about the oceans, whether for example there are long-term changes in the deep-water circulation of the ocean—which extends all the way up to the surface in the waters south of Greenland—large enough to give the clue to climatic trends. We cannot do enough basic work. Until 1959 we relied on measurements of the specific heat of sea-water made by the relatively crude methods of 1889. In every aspect of the subject there is a tremendous lot to do, and we are doing enough to show that the problems respond in a very exciting and rewarding way to modern theoretical and practical methods.

PLANT TAXONOMY AS A SCIENTIFIC DISCIPLINE*

By Dr. R. E. HOLTTUM. *Formerly Professor of Botany in the University of Singapore*

The themes which I wish to develop in the present address are that taxonomic study of vascular plants has just as much claim to be regarded as a scientific discipline as have the more experimental aspects of botany; that much work still remains to be done on problems of basic taxonomy of tropical plants; and that our understanding of British plants is dependent on seeing them in relation to the plants of the tropics.

During the past few years, several statements on plant taxonomy have been published, among the most important being Prof. H. J. Lam's chapter on Taxonomy in *Vistas in Botany* (ed. W. B. Turrill, Pergamon Press, 1959) and Dr. Lincoln Constance's chapter in *A Century of Progress in the Natural Sciences* (Calif. Acad. Sci. 1955). Both these papers include full bibliographies. In the present address I cannot attempt as full a treatment as these authors; my concern is rather to present the situation as it has come to me in the course of my work, most of which has been carried out in Singapore.

When I was a student I received the impression that taxonomy of the angiosperms was regarded as a distinctly inferior form of activity; and though this attitude may not be so prevalent today, there is still a great neglect of taxonomy in our universities, and within the past few years I have heard it stated of three of them that work on the taxonomy of angiosperms is not acceptable for a higher degree. When I went to Singapore I soon discovered that basic taxonomic understanding of Malayan plants was still in a very imperfect state, and that a large number of local species were still unknown. I was therefore impelled to undertake taxonomic study. I began with the ferns, but was soon concerned with orchids, because many people cultivated them, and with bamboos because these were obviously of great local importance and most of the bamboo plants in the Botanic Gardens had lost their names. From orchids I went on to gingers, and from bamboos to grasses and so to sedges. In all these great groups of plants I found that new thought about the basis of classification was needed, and in some cases that established schemes were founded on erroneous observations. As a result of the study of these various groups of plants, I learned a good deal about taxonomy and taxonomic method, and I want next to say something about the thoughts that developed in my mind on the nature of taxonomic study.

First, it has always seemed to me that one reason why further study of taxonomy seems unimportant is the nature of the books in which taxonomic knowledge is presented. A Flora or a Monograph appears to be a complete work, accounting satisfactorily for everything; and it is very difficult to judge such a work without making a rather close study of at least part of the material covered by it, a task few people have the time or opportunity to undertake. Many monographs are however seriously defective for various reasons. Most tropical taxonomic works are based on very incomplete information, and fuller knowledge of known species, as well as of the many new ones constantly being discovered, may necessitate a different arrangement of the whole material. Every family of plants presents a different problem, and without a thorough examination of every part of a plant one cannot have an understanding of that problem. Too often inspection of new plants has been very superficial, a minimum of information being recorded, and thus significant structures have been entirely overlooked. A striking example of this is the family Zingiberaceae. Sometimes the

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earlier monographers made serious errors of observation, and even used erroneous statements as the basis of a scheme of classification. Later workers have tried to fit their own observations into such a scheme, sometimes leading to more confusion. Some people appear to have concluded from this situation that the taxonomic method is useless. Like all other scientific investigation, taxonomy proceeds by a process of trial and error; and the situation simply is that the work is unfinished.

Another reason why taxonomy has seemed a trivial study is that many taxonomic observations are made by the use of a hand lens or at a similar low level of magnification. In fact a great range of taxonomically important structures, not clearly distinguishable by the unaided eye, can be seen by this means. But the degree of magnification is not the important consideration; what is important is first to see clearly what one is looking at, and then to understand how what one sees is related to one's previous knowledge. To see clearly something that no one has ever examined before, whether one is using a hand lens or an electron microscope, is a creative intellectual act; and to realise how a new observation is related to previous knowledge is an act of insight of the kind on which all advance in scientific knowledge is based.

It took several generations of botanists, from the sixteenth century onwards, to see clearly the structure of the parts of flowers with which a taxonomist is mainly concerned and which we now expect every elementary student to understand. The concept of a genus, or group of distinct kinds of plants which yet have a similar structure, gradually developed during the seventeenth and eighteenth centuries, though many genera recognised by Linnaeus were still very artificial. The concept of a family came later, beginning with de Jussieu's book of 1789. We are still far from arriving at satisfactory generic concepts in many families of plants, because in many cases all the possibly relevant facts have not been recorded. And our concepts of families are by no means final. Higher groupings are still subject to much speculation. Speculation is a necessary part of the development of new understanding, and I do not understand what Prof. Lam means when he writes that 'practical taxonomy is not served by speculation' (p. 29). If speculation, leading to further observation, results in a better basic classification, then it has served a purpose. If it leads to no further action, then it is of course valueless. But there is still such a very great amount of morphological observation to be made that I am sure we have not passed beyond the need for speculation.

The idea of evolution brought a new viewpoint on taxonomy, and the earlier idea of 'natural affinity' took on a new meaning. The aim of taxonomy was seen to be the bringing together of plants which are on the same evolutionary line. That aim remains; but the problem is seen to be such a vast one that most botanists have ceased to try to consider it. The modern tendency is naturally to employ modern techniques, and these can only be applied to the investigation of small parts of this vast scheme, mainly to parts accessible in temperate regions, with the results that the wider view is forgotten, or is even thought to be unimportant. It was a shock to me to read in *Discovery* (Vol. 18, pp. 284–5, 1957) the report of a conference on the teaching of biology in which a suggestion was made that it was time that botanic gardens could dispense with collections of plants arranged according to 'Linnean families', and exhibit instead some results of modern experimental work designed to show how evolution can occur. The arrangement of plants in families is not due to Linnaeus, and is something quite different from his sexual system. Though it is still imperfect, the family arrangement does give a very impressive indication of what evolution has done in the past, and this is surely the background against which all modern experimental work must be considered.

It has been emphasised by several recent authors that, in the absence of evidence from fossils, the study of existing plants cannot lead to any definite understanding of their evolution. But such study, if sufficiently thorough and persistent, can at least show natural groups of species, and I believe of genera. And when one has arrived at the fuller conspectus that this study can give, certain possible lines of evolution may present themselves. It is true that sometimes the direction of evolution is not certain; it is not possible to be sure which end of a sequence is the beginning and which the end. In such cases one can look for further evidence, and sometimes that evidence may give a more definite indication of the possible sequence of evolutionary change.

Like any other scientific investigator, the

taxonomist first accumulates facts, and when he has gathered all facts which seem relevant in a particular study, he has to make generalisations based on those facts. The gathering of facts is a conscious process; but generalisation is something which is done by the subconscious part of the mind. One can decide what observations or experiments one will undertake tomorrow; but one cannot decide 'tomorrow I will have a new and significant idea'. My experience is that if I devote a considerable amount of mental effort to making new observations and to thinking about them, sooner or later a generalisation will come into the conscious part of my mind, but its coming is unpredictable. And its value is also unpredictable. A new idea has to be tested; does it make sense? Some people are so pleased with their new ideas that they do not stop to judge them, and probably we are all liable to be prejudiced in favour of the products of our own minds.

The experimental scientist devises experiments to test his new ideas, which he calls theories. A theory which cannot be tested is not scientific; and no test can ever be considered final. The taxonomist may not be able to test his ideas by controlled experiments, but he can do so (as does the astronomer) by making further observations. He may have an idea as to the significance of hitherto unnoticed distinctions between genera, or as to the most natural way to subdivide a complex group of species. He has to decide whether the application of the idea makes sense, as far as existing knowledge goes. Then he must look to see what other facts can be discovered about the plants in question, and whether his new idea still makes sense when this has been done. New taxonomic ideas often lead one to examine structures or behaviours of plants which one had not at first considered (they may never have been investigated by any previous worker), and new observations lead on to further understanding.

The number of data which a taxonomist needs to consider is often very large, and mathematical analysis of the data may be helpful. But the value of such analysis is dependent on the original observations and on assumptions made about them. And the assessment of the results of any taxonomic investigation is always dependent on the scope of factual knowledge possessed by the judging mind. This is called 'subjective judgement', and is thought to be in some way inferior. But surely a judgement based on knowledge is more likely to be valid than one based on ignorance; and no good taxonomist considers any judgement final.

Prof. C. D. Darlington, in his book *Chromosome Botany*, criticises with some justification the practice of taxonomists in naming species, but offers no practicable alternative. He has nothing at all to say about genera and families, but quotes without comment part of Hutchinson's scheme of classification, with suggestions as to how chromosome numbers might be made to fit it; they might also be made to fit a different scheme. At our present state of knowledge of chromosome-structure, the chromosome botanist is just as liable as any other student of a limited field of morphology to make wrong comparisons if he lacks a broad taxonomic knowledge. The first survey has to be made by the taxonomist, using all available morphological facts; only then can the chromosome botanist have any idea where to start his particular work. The taxonomist often makes mistakes or bad judgements in his first survey; cytological observations can sometimes indicate to the taxonomist that he must think again. The final resolution of the inter-relations of species or of subspecific units needs co-operation of taxonomist, experimental cultivator and cytologist. Comparatively few groups of tropical plants have yet reached this stage.

I will illustrate the significance of these statements by reference to some practical problems I have met with in the course of studying various groups of plants. If in so doing I criticise those who have gone before, this is not to show that their work was of no value; all have contributed their share to the sum of knowledge and of understanding. But we can only progress if we examine the work of our predecessors critically, and learn from their mistakes. We shall no doubt leave many more for our successors to discover.

First I would like to say something about ferns. In his presidential address last year to Section K (Botany), Prof. T. M. Harris said, 'the fact that the classification of the more advanced nine-tenths of modern ferns is in considerable turmoil is related to the fact that the fossil botanists of the late Mesozoic and Tertiary have not given the fern men the right information'. No doubt a further knowledge of Mesozoic and Tertiary fossils would be a help to the taxonomist in considering most of the ferns of today; but I would assert that the major cause of

the present turmoil is simply ignorance of existing ferns. The very limited set of facts recorded by taxonomists of the ninteenth century was quite inadequate to resolve the very complex puzzle. In several cases, characters used today for the discrimination of genera were not mentioned. It is only as new observations have been made and their significance realised that progress has been made in the present century. The scheme of Diels of 1899 was a considerable advance on the artificial system of Hooker; but by modern standards it is seen to be full of confusions, many of which are not yet straightened.

It was the misfortune of Prof. F. O. Bower that in dealing with the more modern ferns in the third volume of his book *The Ferns* (Cambridge, 1926) he had not close contact with the leading taxonomists of the time, namely Carl Christensen and E. B. Copeland. As soon as Christensen had completed his *Index Filicum* (1905) he began a detailed survey of the heterogeneous group of species there included in the genus *Dryopteris*, and in a series of papers he showed how most of these species belonged to two quite distinct series, each of which could be subdivided into groups now generally ranked as genera; no hint of this occurs in Bower's discussion of *Dryopteris*. Copeland had shown that the supposed characters of the indusium traditionally used to divide the family *Cyatheaceae* into genera give a quite unnatural arrangement of species, but Bower used the traditional generic names without comment. Copeland had also called attention to some of the important morphological differences between the two very diverse genera *Asplenium* and *Diplazium*, which had been included in one genus by Hooker because of superficial similarity of soral form, but Bower used a species of *Diplazium* to explain his idea of the evolution of the sorus of *Asplenium*. And so one could go on quoting examples of Bower's lack of understanding due to his lack of taxonomic knowledge. In my opinion, Christensen added far more to our knowledge of modern ferns than did Bower, because Christensen had an exceptionally wide and detailed knowledge, acquired by long and patient study of structures thought previously to be unimportant; thinking about this knowledge developed new ideas in his mind, and he could effectively judge those ideas by seeing them in relation to his gathered knowledge.

As an example of the kind of way in which evidence can develop, I will take the tree-ferns, which I have recently been studying. These ferns are divisible into those with marginal sori protected by outer and inner indusia (*Dicksonia* group) and those with superficial sori well away from the margin on the lower surface of the leaflets (*Cyathea* group). The *Cyathea* group were divided by Hooker into those with a cup-shaped indusium (*Cyathea*), those with a not very clearly defined partial indusium (*Hemitelia*) and those lacking an indusium (*Alsophila*), though in fact this arrangement is an over-simplification. Bower was so much impressed by the resemblance between *Alsophila* and *Gleicheniaceae*, the latter certainly a more primitive family, that he considered the non-indusiate condition primitive in the *Cyathea* group of tree-ferns. This involves the assumption that the indusia in Hooker's *Hemitelia* and *Cyathea* are a new evolutionary development, not homologous with the inner indusium of *Dicksonia*. Believing that marginal and superficial sori characterised two great and divergent groups of ferns, Bower placed *Cyatheaceae* and *Dicksoniaceae* in the two opposite parts of his scheme, and he placed *Dryopteris* as a derivative of *Cyatheaceae*.

As regards the subdivision of Cyatheaceae, Copeland had pointed out that the three genera as defined on the form of the indusium, or its absence, were quite unnatural; and my own observations on the tree-ferns of Malaya confirmed this. It seemed clear that the development of an indusium, or its loss (whichever way one read the sequence) had happened on more than one evolutionary line; one could find pairs of species, one in each pair with an indusium and one without, but similar in other features which differed from the other pair. I therefore followed Copeland in placing all Malayan species in one genus, *Cyathea*. But it was clearly necessary to find other characters by which natural groups of species could be recognised within the 800 which constituted the great genus *Cyathea*. To the field botanist, the most obvious possible characters, often unknown to the herbarium botanist, could be seen in the scales at the base of the petiole. At first I thought that there were three types of scales in the species of the Malay Peninsula, but when I suggested to Mr. G. P. DeWolf that he should make a detailed study of them, he found only two types, and this

I have confirmed by further study of a large number of species. A small difference in venation is also associated with the difference in scales. This gave a main division of Malaysian *Cyatheaceae*, independent of indusia.

This does not indicate that the indusium is unimportant; it is useful as a distinguishing character when one has made the main division on scale-characters. But I was perplexed about the indusium in quite another connection. Bower suggested that *Dryopteris* was a derivative of *Cyatheaceae*; but in *Dryopteris* Bower included *Thelypteris* and its allies which, following Christensen, I could see were a quite distinct group of genera. I could see much resemblance between the Thelypteroid ferns and *Cyathea*, but *Dryopteris* proper seemed to belong to quite another alliance. Then I noticed the genus *Culcita*, believed to be a relative of *Dicksonia*, and found considerable resemblance between *Culcita* and *Dryopteris*. Thus I had *Dryopteris* and *Thelypteris* ferns whose sori (especially the indusia) are so much alike that they were long placed in one genus, one of them related to *Culcita*, one to *Cyathea*; but according to Bower the indusia of *Cyathea* and *Culcita* were not homologous. This seemed an improbable conclusion.

I therefore began to think again about the *Dicksonia* group of genera, which I had hitherto, following Bower, placed far apart from *Cyathea* in my scheme, and I was suddenly struck by the resemblance between the *Hemitelia* type of indusium in *Cyathea* and the inner indusium of *Dicksonia*. If these two structures could be regarded as homologous, then the difference between *Cyathea* and *Dicksonia* could be explained by a shift of the sorus away from the margin (an evolutionary development which has certainly occurred in other groups of ferns and can indeed be seen in the Australian species *Culcita dubia*). In habit and in vascular structure, and in the structure of sporangia, *Cyathea* and *Dicksonia* are close together. The major difference remaining is that young fronds of *Cyathea* are protected by scales. those of *Dicksonia* by hairs; but (in addition to scales) some Cyatheas have hairs very like those of *Dicksonia*. If then one thinks of *Cyathea* and *Dicksonia* as rather nearly related groups of ferns, it is clear that the *Hemitelia* type of indusium is primitive in *Cyathea*, and this gives a key to the understanding of evolution in the form of sori within *Cyathea*. At the same time this postulate also implies that the indusia in *Thelypteris* and *Dryopteris* are homologous, and further enables us to formulate a scheme of relationships between the relatively primitive *Cyathea* and *Dicksonia* (with allied genera) and all the more highly evolved ferns with the *Dryopteris* type of sorus. This scheme brings together elements widely separated by Bower, and appears to me to be a much more satisfactory interpretation of the facts.

All this is not intended to show that Bower's work was valueless. He did a great and fundamental work on the comparative morphology of primitive ferns, and this was a stimulus to further work by others. But he did not realise the extremely unsatisfactory nature of the taxonomic scheme set forth by Diels, nor had he any first-hand knowledge of most of the plants with which he was concerned in their natural environment in the tropics.

Looking for a moment at British ferns, we find the species *Polypodium vulgare*, which the tropical botanist sees as an outlying and reduced member of a great tropical family of epiphytes, *Polypodiaceae* in the strict sense (not that of Diels). In Christensen's *Index* of 1905 a great part of this family (and with it most of which is now regarded as the separate family *Grammitidaceae*) was included in a vast genus *Polypodium*; now that this complex of species has been rather tentatively divided into many genera, nobody is really sure of the natural limits of a genus *Polypodium* in the strict sense, and a decision on the matter involves a new study of many tropical and subtropical ferns. Our species of *Dryopteris* (in the strict sense) and of *Polystichum*, are seen as parts of a very complex group of species, especially in northern India and west China, and this group still awaits a rational subdivision. The *Thelypteris* group of genera (which should constitute a family of their own) is a quite distinct and equally complex one, mainly of tropical and subtropical species, in which natural genera have not yet been clearly distinguished. The three British species (excluding those which belong to the genus *Gymnocarpium*) should be placed at least in three different subgenera, probably in three separate genera: *Thelypteris*, *Lastrea* and *Phegopteris*. Figures 1 and 2 show a few of the many Malaysian ferns related to our British *Polypodium Vulgare*.

Fig. 1.—Malayan ferns allied to *Polypodium vulgare*: 1, *Leptochilus decurrens*, showing narrow erect fertile fronds, on rocks by a stream in mountain forest; 2, *Platycerium coronarium*, on a tree in Singapore; 3, *Lecanopteris carnosa*, with fleshy ant-inhabited rhizome; 4, *Microsorium hancockii*, on rocks by stream; 5, *Selliguea feei*, near crater of a volcano in Java; 6, *Dipteris conjugata*, a modern representative of an ancient group of ferns, believed to be of the same stock as *Polypodium*.

Now we will turn to the Orchid family, which in the wet tropics includes more known species than any other family of angiosperms (in Malaya, more than 12 per cent of the total angiosperm flora). The only scheme of classification of the *Orchidaceae* proposed in the present century is that of Schlechter, posthumously published in 1926; this is comparatively little modified from Pfitzer's scheme of 1889, in Engler's *Pflanzenfamilien*. Pfitzer tried to use vegetative characters to distinguish the main subdivisions, because he objected to Lindley's exclusive use of characters of the pollinia for this purpose (he thought the evolution of pollinia was too much correlated with that of pollinating insects to be natural). Pfitzer used terminal as against lateral inflorescences as a main subdividing character; but it seems to me entirely probable that in orchids a terminal inflorescence is primitive, and that lateral inflorescences have been derived from it on several different evolutionary lines, so that a division between orchids with terminal and with lateral inflorescences is not a natural division (and in some cases it is not clear whether there is or is not a terminal inflorescence). The distinction between convolute and duplicate leaves seems to me also one that has probably occurred on different evolutionary lines; the latter condition is mainly found in epiphytic orchids and may well be regarded as an adaptation to the epiphytic condition, which has certainly evolved on several quite distinct lines. Apart from these considerations, an enormous number of new species of orchids have been found since 1889, and old generic concepts often prove unsatisfactory to accommodate many of them, so that there is a great need for revision in detail. The stupendous task of getting a new view of the orchid family can only be attempted by someone who has acquired

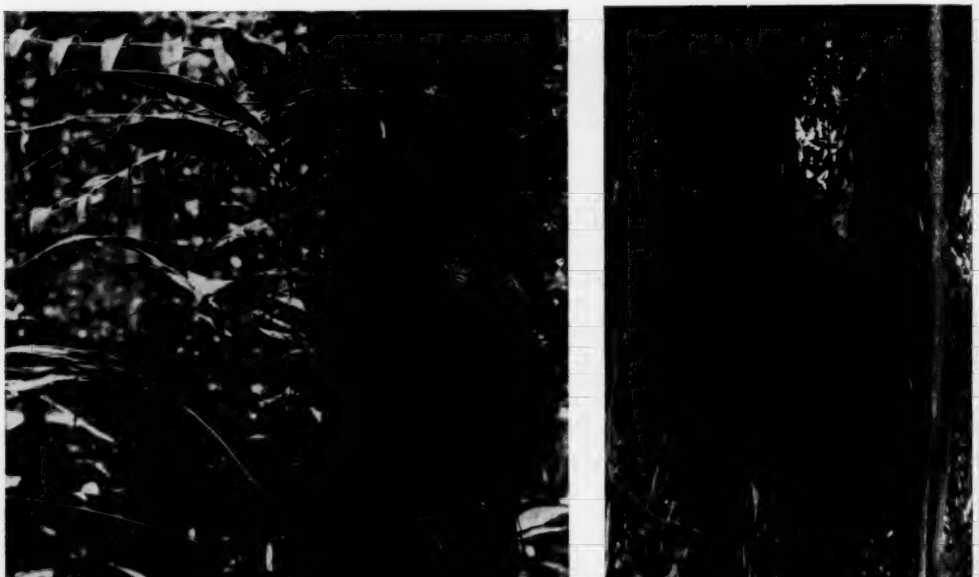

Fig. 2.—Ferns of two more genera related to *Polypodium*. Left: *Crypsinus taeniatus*, on a tree-trunk in forest, with a filmy fern. Right: *Pyrrosia longifolia* (long pendulous fronds, centre) and *P. angustata* (shorter spreading fronds, left) on a tree in Singapore.

an intimate and extensive knowledge of its tropical species. It so happens that tropical orchids have been much in vogue as greenhouse plants in this country for more than 150 years, and during the past century a remarkable and carefully recorded series of hybrids have been made from them. But the growers of these wonderful plants and the academic world have had few contacts, and British botanists have signally failed to use a very large range of material available for their study. In recent years cytological study of tropical orchids has begun in other countries, but it is only within the past year that such study has begun at Kew.

Seen as an outlying part of a mainly tropical family, British orchids appear as peculiar and specialised developments. The genus *Orchis*, so far from being typical of the family, is part of a northern group which have adapted themselves to seasonal temperate climates. Both vegetatively and in floral structure, they are highly specialised. It looks to me as if the most nearly primitive part of the orchid family, if one excludes the *Apostasiaceae*, is to be found in the genera allied to *Goodyera*, which grow on the ground in tropical forests and have no resting season. The great wealth of tropical epiphytes, no less than the geophytes of temperate regions, are more highly evolved in many ways.

The ginger family is one that cannot fail to fascinate any visitor to the forests of the wet tropics. The only monograph of this family is that of Schumann in Engler's *Pflanzenreich* (1904). The part of the family dealing with Malaysia was largely based on a work by the same author published in 1900. When Valeton, a Dutch botanist working in Java, tried to use this publication of 1900 to identify four conspicuous species, he found that they were not only inadequately but inaccurately described, with the result that Schumann's generic concepts were very unsatisfactory. This started Valeton on an intensive study of the gingers of the forest near the mountain garden of Tjibodas, and later the species of *Zingiber* and *Curcuma* which were universally used for flavouring food and in village medicine in Java. In my turn, when I came to make a survey of this family in Malaya, I found that I had to revise generic concepts and to use (as did Valeton) characters not mentioned by Schumann to distinguish genera. When Loesener came to prepare the account of this family for the second edition of the *Pflanzenfamilien*, he mentioned Valeton's work, but could not use it because the necessary information was still lacking for a large part of the family. This family, almost confined to the tropics, still needs a complete revision, and much new field work in the wet tropics. I am sure that there remain a good many species still quite unknown in the forests of the great islands of Malaysia, and that generic boundaries are still tentative throughout the family.

Bamboos are among the most wonderful of plants in precision of construction and of development, and they are also among the most useful to man in the tropics and subtropics, yet they have been sadly neglected by botanists. The scheme of classification still to be found in Hutchinson's *Monocotyledons* (Cambridge, 1959) is little altered from that of Bentham in *Genera Plantarum* (1882) and Bentham took it from Munro's monograph of 1868. The basis of subdivision of the bamboo tribe into subtribes in this scheme is the structure of the fruit, but so few different fruits were known to Munro, and their structure so little understood, that the whole of his scheme rested not on facts but on errors of observation. The fruit of *Melocanna* and *Ochlandra* is called a berry, and indeed it has a fleshy pericarp; but this group of genera (including others which have small fruits) is primarily to be distinguished by its peculiar ovary-structure, and the remarkable feature of the fruit in *Melocanna* and *Ochlandra*, unknown to Munro and Bentham, is that a resting seed is never formed. The embryo grows continuously, absorbing the whole of the endosperm and apparently taking also further nourishment from the parent plant, and puts out roots and leaves before the fruit falls to the ground. Another genus, *Melocalamus*, behaves in the same way, but in its structure of ovary and spikelet it is quite different from *Melocanna*. *Dendrocalamus* is quite wrongly stated to have a berry-like fruit and is placed with *Melocanna* in Munro's scheme, but its fruit-structure is quite indistinguishable from that of *Bambusa* and *Gigantochloa*, genera placed by Munro in another sub-tribe. J. S. Gamble, who was one of the few botanists to study bamboos extensively in the field, and who wrote an excellent monograph on Indian bamboos, knew something

of the discrepancies of Bentham; but such was Bentham's prestige that Gamble did not try to alter the scheme, though his generic descriptions in some cases did not conform to it. I discovered this when I tried to understand the bamboos of Malaya, and was able to examine fruits of some of them. Now at last Dr. F. A. McClure in America is working on a new monograph. He has a knowledge of a wider range of living bamboos than any previous man has ever had, both in the tropics of Asia and America.

Bamboos may seem far from the British Flora, and no doubt they have become very specialised vegetatively; but it seems to me that the bamboos of tropical Asia have preserved primitive features of the structure of flower and spikelet, so that they may well help us to a better understanding of the excessive complexities of evolutionary development in the rest of the family *Gramineae*.

The last family I will mention is the sedge family, *Cyperaceae*. The principal genus of *Cyperaceae* in Britain is *Carex*, which includes a very large number of species and ranges throughout the whole world; but it is certainly one of the most highly specialised parts of the family. To understand something of the primitive condition of the family, one must look at the species of the forests of the wet tropics (the species of *Carex* also which give a key to the understanding of that genus are tropical species, namely *Carex indica* and its allies). The family is still often placed alongside the grasses; but though superficially grasses and sedges are much alike, they have many important differences and I believe that they have had very different origins.

Long ago Bentham wrote a lot of good sense about *Cyperaceae*, but it has been forgotten because of the quite different scheme proposed by Pax in the first edition of Engler's *Pflanzenfamilien*. Pax there placed the tribe *Scirpeae* (including the genus *Cyperus*) and *Rhynchosporeae* in different subfamilies. When a hybrid was found by Fernald in America between a *Cyperus* and a *Rhynchospora*, it was regarded as a wonderfully wide cross; it should have led to a re-examination of the validity of the subfamilies of Pax. If a supposed difference in structure of the axis of the spikelets is not admitted (and I see no evidence for it) one finds it difficult to state in precise terms a distinction between *Cyperus* and *Rhynchospora*, which I believe to be closely related genera, so that a hybrid between them is not surprising.

The examples which I have given, taken only from a few families with which I happen to have particular acquaintance, show how very inadequate is present taxonomic knowledge. If these examples constitute a fair sample of the whole range of vascular plants, the amount of new investigation and new taxonomic thought needed is very great. Meanwhile the native vegetation of the tropics is disappearing at an alarming rate, before we have an understanding of what the world is losing in the process.

In the United Kingdom, the study of plant taxonomy is mainly carried on at the Royal Botanic Gardens, Kew, at the British Museum (Natural History) and at the Royal Botanic Garden, Edinburgh. At all these institutions are collections of preserved material from all parts of the world, and continual additions are being made. At Kew also is a collection of living plants second to none in the whole world. At all institutions are excellent libraries, where the results of past taxonomic studies are almost all to be found. My impression, after working for six years fairly continuously at Kew, is that the collections at Kew and the Natural History Museum are consulted more by foreign visitors than by botanists from British universities. There is no formal association between either Kew or the Natural History Museum and the teaching departments of British universities, though the wealth of material available at both institutions affords opportunities for research in taxonomy unsurpassed in any other country. There is now, as never before, quick and easy means of travel to tropical regions, but in order effectively to take advantage of a tropical journey, a botanical explorer needs to learn what is already known about the plants with which he is to be concerned. The days of general uncritical collecting, in most parts of the world, are over, but there is great need to fill the gaps in our knowledge, and to supplement acquaintance of dried specimens by a study of the living plants. This kind of study is of course better done at research institutions in the tropics, of which there are now several actively at work; but still the basic knowledge needs to be provided by the historic collections in the world's great herbaria, where a vast amount of unstudied material also awaits attention.

INVESTMENT IN EDUCATION IN NIGERIA*

By Sir ERIC ASHBY *The Master, Clare College, Cambridge*

I. THE PRESENT

An Obsession with Education

Nigerians are being born at a rate of something like two a minute. Each year about 800,000 Nigerian children reach the age of seven. One of the questions which confront the newest and largest African nation is to decide what sort of education these children are to have. For some years, while they have been taking up the reins of self-government, the Nigerians have shown an intense interest—amounting to an obsession—in education. The doors of school and college are their only entrance to modern technological civilization. The degree has become their most potent symbol of status.

If you drive through Lagos at night you may see circles of children under the street lamps, studying for School Certificate. If you go into the classrooms of primary schools you may see teachers working for the London University General Certificate of Education (probably in Scripture or Geography) by correspondence, while the children write essays or do sums. Every year thousands of clerks, shophands, and junior government servants enter for the G.C.E. after private study. Scores of establishments rejoicing in names such as *Never Fail Coaching College* and *Pinnacle of Success Correspondence School* offer to satisfy this hunger for ... what? The optimists say 'education'; the cynics say 'a certificate which confers higher status and entitles its holder to better pay'.

To harness this enthusiasm and to use it in the national interest is one of the massive problems which face Nigeria's leaders. Even before independence great efforts had been made to tackle this problem. It is in the forefront of politics. Before the last elections some of the newspapers published declarations of policy from each of the three big political parties. About half of these declarations was devoted to education. And at the first meeting of the Federal House of Assembly after independence copies of a book entitled *Investment in Education** were distributed to the members. This book contains proposals for a blueprint for post-School Certificate education in Nigeria over the next twenty years.

What has been accomplished in Nigerian education? And what do the Nigerians hope to accomplish by 1980?

Universal Primary Education

The most dramatic accomplishment is universal primary education (known as U.P.E.). In the Western and Eastern Regions, which contain just under half the population of Nigeria, U.P.E. is a fact on the statute book and is rapidly becoming a fact in the countryside. Fifteen years ago only about 280,000 children in the Western and Eastern Regions were at school: last year in these Regions alone over 2,000,000 were at school. In the Moslem area of the Northern Region there has for centuries been another kind of primary education, namely that in the Koranic schools conducted by mallams, still to be found in every town and village in the 'holy north' of Nigeria. Accordingly Western education has spread more slowly there. U.P.E. has been introduced only in Kano Emirate; in some areas barely 10 per cent of children go to Western schools.

U.P.E. is by no means an unmixed blessing. It caught the imagination of politicians, some of whom advocated it with enthusiasm but without regard to its difficulties. On this account it was introduced prematurely, before there were anything like enough

* Reprinted by courtesy of *Progress*, the Unilever magazine.

* *Investment in Education*. Report of the Commission on Post-School Certificate and Higher Education in Nigeria, 1960. Lagos: Federal Government Printer, London: Crown Agents, 4 Millbank, S.W.1. Price 5s.

trained teachers; and to this day nine-tenths of the teachers in primary schools are not properly trained for the job. In the southern part of the country the whole machinery of primary education is evident: schools, desks, black-boards, books, teachers; but there is very little cutting edge to the machine, and the education which tens of thousands of children are getting is dangerously deficient. Nevertheless, it is using up, in the Eastern and Western regions, as much as two-thirds of the education budget. Attempts to diminish this expenditure by the introduction of fees led to riots, and had to be abandoned. This is the second drawback of U.P.E.: it consumes so much of the education budget that not enough is left over for secondary schools, teacher-training colleges, and technical education.

Secondary Grammar Schools

Above primary school the educational pyramid contracts sharply. In 1958 about 650,000 pupils entered primary schools, but only about 12,000 entered secondary grammar schools (in a mature Western community the corresponding number to enter secondary grammar schools would be at least 130,000). It needs no imagination to see how this situation endangers the whole educational system. Because too few Nigerians go on to grammar school there are too few well educated young people available for teaching; this obliges the teacher-training colleges to find their recruits from young people with no more than a primary schooling and this in turn weakens the schools. Nearly half those who teach in teacher-training colleges, and over half those who teach in secondary grammar schools, are simply not equipped for the task. The danger, therefore, is that Nigeria will continue to expand its school system and to put more and more money into it, but that standards of teaching may nevertheless deteriorate. Quantity will increase; quality will diminish. This danger cannot be averted except by a massive programme of overseas aid to Nigeria; the scale of the programme is discussed below.

Higher Education

After School Certificate the pyramid contracts even more sharply. According to the latest statistics only 553 pupils are doing sixth-form work in schools. Now entry to most professions in Nigeria (e.g. accountancy, law, medicine, engineering) is anchored to standards similar to those required for entry to professions in Britain; so this trickle of sixth-form pupils does not begin to meet Nigeria's need for professional men and women. Again there is a danger: in its haste to Nigerianise its professions, the country will be tempted to lower its educational standards. Jobs must be filled; and for the present only outside aid can prevent them from being filled by inadequately qualified people.

At the apex of the educational pyramid stand the universities. There are two of them: University College, Ibadan, which has already acquired an international reputation and has over 1000 students; and the University of Nigeria, at Nsukka in the Eastern Region, which admitted its first students (some 250 of them) in October 1960.

University College, Ibadan, is in what is called special relation with the University of London and teaches for London degrees. Its standard of work, therefore, is in all respects equivalent to that done in the University of London. The University of Nigeria is likely to submit its standards to the arbitrament of two universities who will act as joint sponsors: Michigan State University and the University of London. University degrees earned in Nigeria are, therefore, secured to international standards. This is a fact of the greatest importance to Nigeria's future. If this anchor drags, it might be difficult to maintain in Nigeria an educational system which could hold its own, and compete successfully in the Western world.

Despite the weak trickle of pupils from sixth forms there is great pressure on university places, for thousands of Nigerians who have never had an opportunity to do sixth-form work toil in their spare time (and often in their working hours too) at correspondence courses for G.C.E. Some 12,000 entered for the examination in 1960. The failure rate is very high, but a substantial number do qualify to enter universities—far too many for the vacancies in Ibadan and Nsukka. Some of the disappointed applicants secure places overseas: in 1958–9 there were 881 Nigerians enrolled in universities in the United Kingdom alone, and several hundred more in other countries. The enthusiasm and the patient hard work which goes into this enterprise is very moving. But it is, of course, far too precarious an arrangement to satisfy the needs of a new African nation.

Technical and Agricultural Education

Three out of every four Nigerians work on the land and seventeen shillings out of every pound earned from Nigerian exports come from agricultural products. Yet agricultural education is held in low esteem, and it is hard to persuade young people to enter the agricultural schools. At one time even the Faculty of Agriculture at University College, Ibadan, had unfilled vacancies. It is no exaggeration to say that one effect of education on a Nigerian is to draw him away from the land, away from village life. It is a passport to the pavements and offices. He is lured by the city lights to a job where he can escape from the tribal hierarchy, the grass hut, the hoe and the matchet.

Technical education suffers a similar low esteem; even at its higher levels it is unpopular—unless it carries the status of a university degree. The consequence is that schemes for developing sub-professional technological education (the local equivalent of Higher National Certificate) languish through lack of support. Every engineer wants to have a B.Sc.; only if that is out of reach will he accept training in a technical institute.

There are two reasons for this disinclination to work for sub-professional qualifications. One reason lies in the salary structure. On the one hand posts which have always been filled by Nigerians are paid according to the 'real value' of labour in the country; and this is much lower than its real value in Britain. On the other hand posts which have in the past been filled by expatriates are paid on scales which are higher than the salary levels for corresponding posts in Britain. Consequently, there is in many walks of life an enormous gap in salary between the professional and the sub-professional man: the man with a degree and the man without a degree. The second reason is that education, for many Nigerians, is a weapon for displacing the expatriate. It is the spearhead of Nigerianisation. And it is the administrative job, the office job, the job where the man gives the orders (the job, as one Nigerian put it, 'which entitles me to clap my hands and shout: "Boy! Whiskey!"') which confers status. The man who sinks an artesian well, or supervises a demonstration farm, or serves as foreman in the railway workshops (and these are among the men Nigeria most urgently needs) does not expect to be regarded as the new *élite*. What Nigeria needs as much as overseas aid is a self-denying decision to narrow the gap between the salaries of the graduate and the non-graduate, preferably (for this is the only solution the country can afford) by reducing the salaries paid to graduates; coupled with an internal campaign to emphasise the national importance of the practical man: the agronomist, the plant-engineer, the N.C.O.'s of the professional world—in brief to confer dignity upon technical skill.

II. THE FUTURE

How Far and How Fast?

Since Nigerians assumed political control of their own affairs the progress they have made in building up an educational system is truly astonishing; and the sacrifice they have made, too: for about 40 per cent of the whole Regional budget in the Eastern and Western Regions is spent on education, and this means that other public services have been curtailed. Political leaders of all parties are committed to ambitious educational programmes. They are, naturally, in a hurry. The people are pressing them. There is no danger of apathy over education: the danger is rather that the people will regard education as a panacea for all their troubles. A School Certificate awakens expectations; for thousands, these expectations will inevitably be unfulfilled. Unfulfilled expectations generate disillusionment, frustration, and discontent: and education, which began as a lodestar, may end as a mirage. If opportunities for education are delayed too long, there will be discontent; if they are expanded too rapidly at the expense of quality there will be discontent. What should Nigeria's educational policy be?

It was to answer this question that the Federal Government appointed in April 1958 an international Commission, consisting of three Nigerians, three Americans and three British, to prepare a plan for post-School Certificate education over the next twenty years. The Commission was financed by Carnegie Corporation of New York. It completed its report in time for Nigeria's independence, and it was this report—*Investment in Education*—which was distributed to members of the House of Assembly last October.

Once they had sized up the situation, the members of the Commission had to make a major decision of policy. Should they predict how much Nigeria can

afford to spend on education between now and 1980, and then propose cautious, reasonable ways in which these modest funds might be spent? Or should they decide how large an educational system Nigeria needs if she is to take her place in an age of technology, if she is (as it were) to become 'educationally airborne'? Let the members of the Commission speak for themselves:

> The upsurge of Africa is so dramatic and so powerful that proposals which today appear to be reasonable and sensible will in a very few years appear to be short-sighted and timid. One has only to read reports on West African education written fifteen years ago to realise how even wise and experienced men under-estimated the pace at which West Africa is growing up. One of the wisest of them wrote: 'Somewhere, in West Africa within a century, within half a century ... a new African State will be born. It will be strong. Its voice will be listened to ... It will have a vital need for counsellors, its own counsellors. Now is the time, and the time is already late, to train them for their work.' That was written in 1945. Already by 1960 the prophecy had come true.
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> To approach our task, therefore, we have to think of Nigeria in 1980: a nation of some 50 million people, with industries, oil, and a well-developed agriculture; intimately associated with other free African countries on either side of its borders; a voice to be listened to in the Christian and the Moslem worlds; with its traditions in art preserved and fostered and with the beginnings of its own literature; a nation which is taking its place in a technological civilisation, with its own airways, its organs of mass-communication, its research institutes.
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> Millions of the people who will live in this Nigeria of 1980 are already born. Under the present educational system more than half of them will never go to school. Like people elsewhere, their talents will vary from dullness to genius. Somehow, before 1980, as many talented children as possible must be discovered and educated if this vision of Nigeria is to be turned into reality. This is a stupendous undertaking. It will cost large sums of money. The Nigerian people will have to forgo other things they want so that every available penny is invested in education. Even this will not be enough. Countries outside Nigeria will have to be enlisted to help with men and money. Nigerian education must for a time become an international enterprise.

This is the challenge which the Commission has put in front of the Nigerian people. Already there are signs that the Federal and Regional governments accept the challenge. There are signs, too, that if Nigeria asks for aid—in men and money—she will not be disappointed.

L.E.A.P.

The Commission makes sixty-four proposals. Some of these are conventional and deal with internal educational policy. Others—a few of them are mentioned below—are unconventional and require international co-operation.

In the foreseeable future English will remain the only common language among Nigerians. Nigerians should, of course, be encouraged to adapt the English language to their own temperament and imagination, just as the Irish have done, and the Americans. But it remains essential that English spoken in London and Washington should be intelligible to Nigerians in Lagos; and there is no assurance, on the present standards of English teaching in primary schools, that this will be so. To supply remedial courses in English to some 80,000 primary school teachers is no easy matter. One of the Commission's proposals is that the residence halls of University College, Ibadan and of the Nigerian Colleges of Arts, Science and Technology (most rooms in which are unoccupied from June to September each year), and the halls of the University of Nigeria when they are built, should be occupied by primary school teachers as soon as the students go down, and that chartered aeroplane loads of teachers should be flown out from England (after some suitable preparation in the teaching of English as a foreign language) to conduct intensive refresher courses. If this proposal were adopted it would not be very long before at least one teacher in every primary school in Nigeria could have attended a refresher course. This, backed up by widespread English lessons over the radio (also one of the Commission's proposals) would do something to create higher standards of English in schools.

But this is only a minor matter. The desperate need is to bridge the gap between Nigeria's most precious national asset—her 15,000,000 or more children under the age of 18—and the posts of skill and responsibility which must be filled in the next 20 years if Nigeria's aspirations are to be realised. The Commission estimates that the flow of high-level manpower into government departments, public services, industry, and the professions should be at the rate of at least 8000 a year. Already there are enough children in primary schools to supply this flow, but beyond primary school the educational system has to be enormously enlarged. How is this

to be done? By opening more secondary schools? Where are the teachers to come from? Before there can be teachers there must be more students in teachers' colleges and universities; but there cannot be more because there are not enough secondary schools to supply the recruits.

To resolve this impasse the Commission proposes an international Loan and Educational Aid Programme (L.E.A.P.). Its purpose is two-fold: to build up by 1970 a force of Nigerian graduate teachers sufficient to staff the secondary schools, technical institutes, and teacher-training colleges, and to ensure that between now and 1970 there are enough secondary school teachers in Nigeria to man the classrooms for at least the minimum number of children for the nation's needs in the 1970's.

If the L.E.A.P. programme is adopted there will be about 7000 graduate teachers—all Nigerians—by 1970. The first source of these must be Nigeria's own universities, but these alone—however rapidly they develop—will not be able to supply the need in time. The balance must come from two sources: Nigerians who graduate from overseas universities, and expatriates who come out to Nigeria on short contracts. The Commission worked out that the cheapest practicable way to conduct this operation would be to send some 600 Nigerians a year overseas for training, starting straight away, and to make up the deficit by importing expatriates on (say) three-year contracts. This would cost about £19,000,000 between 1960 and 1970. If fewer Nigerians are sent abroad for training and more expatriates imported on contract the cost goes up (if only 300 Nigerians a year go overseas, for example, the cost of the operation would be of the order of £33,000,000; and if Nigeria relies on her own universities as the sole source of training the cost will be of the order of £48,000,000).

So the Commission recommends that the manning of classrooms in Nigerian secondary schools (and technical institutes and teacher-training colleges) should become for ten years an international enterprise. A group of overseas countries should between them offer places in universities for the 600 Nigerians a year who will go abroad for training; each of these countries should set up what might be called an African Teaching Service, which would recruit suitable graduates for three-year contracts and guarantee to re-absorb them into their own teaching services, with no loss of seniority or pension rights, when their contracts end.

The Commission proposes an international investment in education. There is good reason to hope that the L.E.A.P. programme, if properly organised, would catch the imagination of young men and women in the U.S.A. and the British Commonwealth. The idea of service in Africa appeals to thousands of young graduates; but the need has to be focused for them, and the way to meet the need has to be made clear. It is a massive and unconventional proposal, but nothing less will meet Nigeria's needs.

New Universities

One other example of the Commission's blueprint is worth a comment, namely the recommendations on universities. If Nigeria's need for high-level manpower is to be met there must be at least 10,000 students in universities in the 1970's. This will require as a start four universities: one in each Region and one in Lagos. There are likely in fact to be five, for the Western Region, which is already served by University College, Ibadan (supported by Federal, not Regional, funds), plans to build a university in the Region which will be supported by Regional funds.

The great merit of the association of University College, Ibadan, with the University of London has been the high standard of degrees. An inevitable demerit of this association has been the inflexibility of the curriculum. The Commission is convinced that high standards are not incompatible with flexibility, and for the new universities it urges a much greater diversity of studies. Careers such as accountancy, banking and insurance, which are entered through an exclusively 'office-based' training in Britain, should in Nigeria be entered through a 'sandwich' training, in which periods of formal study at the university alternate with periods o practical experience in an office. This, and other unconventional forms of higher education, are put forward by the Commission as the pattern for Nigeria's new universities. It allows some opportunity for the specialisation which is already to be found in Ibadan; it adds something of the breadth of Scottish university education; and it includes some of the diversity of the American land-grant college.

The Core of the Curriculum

It is at once touching and exasperating to see Nigerians, whose homes are reached only through tracks in the jungle, graduating with honours degrees in Classics: touching because some of them still believe that Latin is a white man's magic (the secret of success for the Resident, the Permanent Secretary, the District Officer); exasperating because the roots of African culture lie in Africa and the Middle East and not north of the Mediterranean. Arabic and African studies should be at the core of the humanities in Nigeria. That they are not so is simply because the Englishmen who prescribed the curricula for Nigerian education were ignorant of these studies. A few years ago Nigeria's most distinguished historian returned from Britain to University College, Ibadan. He said he wanted to work on African history. He was curtly told there is no such subject. He had to return to Britain, where he did have an opportunity to work on the history of his own country.

It is late, but perhaps not too late, to illuminate this blind spot in Nigerian education. African studies should be an obligatory subject for all Africans who aspire to higher education: African history and antiquities, its folklore and languages, its societies and its agriculture. To this end the Commission proposes that there should be institutes of African studies in all Nigerian universities. In a report on higher education which is severely pragmatic this is a most important and most welcome emphasis. For it would not profit Nigeria to gain the Western world and to lose its own soul.

THE REVOLUTION IN AGRICULTURE*

By Sir WILLIAM SLATER, K.B.E., F.R.S.

Agricultural revolutions have their origins in economic and social causes; the Tudor enclosures from the desire for personal gain; the Hanoverian enclosures from the need to provide food for a rapidly growing industrial population; and that through which we are now passing from military and economic crises. But, although the forces which begin an agricultural revolution are economic and social, the impetus which carries it forward is provided by the new techniques brought into use to meet the new situation. When the forces which have started a revolution have either spent themselves, or have been contained by technical progress, the revolution continues until the pattern of agriculture has been so changed as to allow the new methods to be fully incorporated into farming practice. A new farming tradition then emerges, accepted by future generations of farmers as inevitably right, until another economic upheaval begins a new revolutionary era.

The revolution through which we are now living had its roots in the First World War. This catastrophe struck a people, who for nearly half a century had relied on their industrial wealth to purchase cheap food from overseas, and who had relegated agriculture to an unimportant place in the national economy. Those amongst us, who are old enough, will remember the agricultural picture in late Victorian and Edwardian England. A land where permanent pasture, often of inferior quality, predominated; where plough and thrashing machine were rusting in disuse, and where liquid milk production, based on imported feeding-stuffs, formed by far the most important part of the industry. Except for a few bright spots, such as the production of vegetables, fruit and potatoes, farming was profitable only if the exhaustion of its capital resources was ignored. Rich men, deriving their wealth from industry, were content to invest money in country estates, expecting no return other than the social prestige attached to a country property. They were prepared to charge low rents to tenants, whose farming maintained the sporting and other amenities of the estate; if they had any farming interests these were most often in the breeding and showing of pedigree cattle.

The landlords, who had no source of income but their land, were gradually becoming bankrupt. They had been forced to reduce rents to enable their farmers to live, and had no funds available for the proper maintenance of their land and buildings. Farmers, even with the low prevailing rents, were surviving only by exhausting their land and restricting expenditure to the absolute minimum. The farm worker, although his wages had improved, was still amongst the lowest paid of all craftsmen. He remained in the townsman's mind as 'Hodge', the slow-moving, slow-thinking, cap-touching peasant, who had not had the initiative or wit to move into the town, where good wages were to be had and where there was a chance of rising in the social scale, an opportunity denied to the farm worker in the rigid class structure of the countryside.

Such was the condition of farming, when in 1916–17 the submarine campaign forced on Britain the need to produce a large part of her food at home. The need was met by the widespread ploughing of permanent pastures and a return to arable cropping.

Farming became once more an important and profitable industry, but it did so by returning to the good farming of 1870, not by moving forward to

* Presidential Address delivered to Section M (Agriculture) on August 31, 1961, at the Norwich Meeting of the British Association.

new levels of technical efficiency, which would have enabled it after the war to compete with cheap food, produced extensively overseas. When prices broke in the early 'twenties, and the Corn Production (Repeal) Act removed both support for corn prices and abolished the Agricultural Wages Board, farming began to return rapidly to its pre-war state. It is not my purpose to discuss the vicissitudes of farming during the inter-war years, nor the shifts which were made by the formation of Marketing Boards and other economic means to save it from bankruptcy. What, however, was of great importance in carrying forward the present agricultural revolution was the impetus which the temporary prosperity and the subsequent collapse of farming gave to research and education. It was realised that, if British agriculture were to compete, it must rise to much higher levels of technical efficiency. This understanding of future needs was shown by the Government's attempt to meet the farmers' complaints over the Corn Production (Repeal) Act by the provision of a million pounds to be spent in five years on education and research.

The years following the war saw the establishment of many new research stations and the expansion of those already in being. Although during the depression of the late 'twenties and early 'thirties there seemed little opportunity for the results of this research to be applied, there remained a firm belief in the minds of those concerned with research that the time would again come when more food must be grown at home. This belief arose from the knowledge of the growing world population, the desire of the less developed countries for a higher standard of living and the exhaustion of the virgin lands from which much of our food came.

The output of work from the universities and research institutes in the twenty years between the wars, often carried out with few men and inadequate equipment, was both high in quality and large in quantity. Stapledon and his colleagues had demonstrated the value of ley farming with grasses and clovers bred for the purpose. The preservation of grass as silage and hay had been greatly improved. The work at Rothamsted had shown the way to better fertiliser practice and Wallace at Long Ashton had demonstrated the importance of minor nutrients in plant growth. The control of many plant pests and diseases had been greatly improved, new varieties of cereals and potatoes had been bred which were capable of responding to higher fertiliser applications.

Research workers in genetics had shown that the art of animal breeding could in time, when the necessary quantitative records were available, become a science. Nutrition chemists had demonstrated the importance of the vitamin and mineral requirements of farm animals and the value of scientifically balanced rations. Our knowledge of the physiology of reproduction and of lactation was greatly extended and the first steps were taken in the evolution of the technique of artificial insemination. Many of the diseases of farm animals were either prevented or controlled. Most important of all a vast store of fundamental knowledge was built up, which was available as a basis for the solution of applied problems as they arose.

As a result of these years of devoted work, when war again called for a great effort from our farmers, the increased output was not obtained as in the first war by a return to high arable production after the manner of the last century, but by developing and applying the new techniques which had been made available.

The state of agriculture in 1939 was in many ways similar to that in 1914. Dairy cows, beef cattle and sheep were grazing large tracts of poor permanent pasture supplemented by the free use of imported concentrates; pig and poultry production depended on cheap imported materials; more tractors and other machines were in use, but the horse still provided much of the motive power; the level of fertiliser practice was far too low and the yields of crops little higher than in 1914. The farm worker was lowly paid—he received little more than half of the average wage in all industries—and the number of men on the land had fallen. The net annual output of agriculture in the United Kingdom was little more in the period 1935–9 than in that of 1911–13. Various Government measures in the 'thirties helped to maintain the acreage of cereals, but the total arable acreage declined.

The first step in increasing food production in 1939 was, as in 1916, to plough up the permanent pasture and return the land to arable farming. The approach to the task was not, however, by returning again to the farming of 1870; in 1939 the goal, from the outset, was to apply the knowledge which had

been won by research and to move forward into a new era of farming based on a high level of technical efficiency. Moreover, Government and farmers alike looked on the raising of the level of agricultural production not as a war-time measure only, but as the pattern of farming in the future. Whilst therefore steps were taken for the immediate increase of production, it was always in the minds of those responsible at all levels that the ultimate objective was a steadily rising standard of efficiency. No limit either in time or in extent was set for this programme; it was tacitly accepted that efficiency could continue to rise so long as scientists continued to produce the necessary knowledge to maintain the progress. It was expected that the growth would be initially rapid owing to the incentive provided by the war-time need for survival and the large volume of unused scientific results awaiting application. Equally, it was accepted that as the accumulated products of research were applied, the work of the scientists must be intensified, in order that new facts and ideas would be continuously available to maintain a steady rate of progress. This belief in the value of science led to the expansion of agricultural research, even during the worst days of the war, an expansion which was continued at a rapid pace when with peace the necessary men and materials were again available.

One question, which was never really answered and which still remains largely unanswered, was the real meaning of agricultural efficiency. During the war the question was not asked; all that was required was the maximum yield regardless of cost. This remained virtually the sole criterion until rationing was no longer necessary; from then onwards new conflicting criteria began to be used. The farmers as a whole still thought of efficiency as maximum production at guaranteed prices based on subsidies. The Government, under pressure to accept growing imports of food at lower prices (often, it must be said, uneconomic prices) and faced with a large bill for subsidies on home-produced food, began to think of efficiency, not in terms of maximum production, but rather in the lowering of the cost of production and the limitation of the quantities of home-grown food, except where expansion was possible at competitive prices calling for no further support by subsidies. This difference of view colours the discussions during the review of agricultural prices each year, and on the solution which is finally reached will depend the future pattern of farming. The resolution of this conflict will rest not only on the extent to which the body of farmers as a whole are willing to apply the available technical advances to the full, but also whether they will accept the changes in the structure of the industry, which are essential for the achievement of this end.

In order to attempt an assessment of the technical advances and structural changes involved, it is necessary to study what had taken place between the beginning of the war and the late 'fifties, when the question of how far we should expand our home food production began to be seriously questioned.

The war-time plan in 1939, as in 1916, involved the ploughing of permanent pasture, but the selection of the land for ploughing the crop to be grown and the fertilisers to be used was no longer haphazard but scientifically based. Arrangements were made for the examination of fields scheduled for ploughing for freedom from pests, particularly wireworm, and for nutritional status. The farmer was then advised as to the first crop to take from newly broken land and the fertilisers essential for a reasonable yield. The available fertiliser supplies were rationed and directed to the places where they were most needed, and farmers were encouraged to use good seed of tested varieties and to take every precaution to protect their crops against pests and diseases. The shortage of labour was made up, not only by the means used in 1916, but also by supplying to the farmers all the tractors and implements, which could be imported or manufactured at home.

In the long-term plan, the newly broken land did not return to permanent pasture, but formed part of a ley-arable rotation, the plough being taken regularly round the farm. In this way the high arable acreage could be retained, whilst the leys by proper management provided, on the remaining acreage, more keep for stock than all the permanent pasture originally broken. At the same time the crops taken after a well managed ley were known to give higher yields per acre.

The results of these efforts during the war years were not, however, strikingly different from those of the First World War. The yields of cereals and potatoes showed no marked increase, the overall increase in production being roughly proportional

to the additional acreage under cultivation. Milk production rose by roughly 5 per cent, but egg production was down by over 15 per cent, beef and veal by 7 per cent, mutton and lamb by more than a quarter and pig meat by over a half.

The explanation, for what at first may seem a disappointing result following the application of new scientific techniques, is not difficult. The farmers were only learning these new methods and doing so under most difficult conditions. Much of the land being ploughed had been badly neglected; it was often poorly drained, infested with weeds and denuded of plant nutrients. It frequently called for special fertiliser treatment to remedy marked deficiencies, deficiencies which were often recognised too late for effective action to be taken to save the crop. Although by 1946 the amount of phosphate used was more than twice that in pre-war years and nitrogen nearly three times as much, little more than one-third more potash was available, and this in many areas was the limiting factor in crop production.

Finally and most important of all, the time had not been reached when the leys sown on the arable land which had been cleaned and well fertilised through a rotation, came into production. Hence the output from the temporary and permanent grass had fallen, if not in proportion to the reduced acreage, sufficiently to cause a marked drop in the beef and mutton supplies. The dairy herd producing liquid milk had to be given the first share of the products of the grassland and of any grain and other concentrates available. Pigs and poultry which normally required grain and imported protein, had to make shift with limited supplies made up with waste materials.

By the end of the war farmers had, however, seen the advantage of the new techniques and acquired some skill in their use. For the following decade the produce of their farms was required in maximum quantities at prices which were attractive to any farmer of reasonable competence, and highly profitable to the man with a well-organised farming business using all the modern techniques. There was, therefore, both economic advantage and pride in the newly won skills, to encourage farmers to go ahead with the original plan of technical advancement.

The shortage of fertilisers was no longer a handicap; between 1946 and 1956 the amount of potash used was nearly doubled and the nitrogen increased by more than half. The phosphate increased for the first four years and then declined to the 1946 level as the need for heavy dressing fell, due to the residual value of the applications over the previous years. Moreover, during the post-war decade the farmer was provided with new technical aids which had not been at his disposal earlier. Perhaps the most important was the new range of selective herbicides which had been evolved as a result of fundamental studies of the nature of the substances responsible for plant growth. These materials have had a profound effect on farming practice. They have enabled the farmer to keep his fields clean with the minimum of cultivations; it is rare now to see a field of poppies or of charlock. At the same time they permit him to experiment with his crop rotation in ways which would have produced disastrous results when he had to depend on cultivation to keep his land free of weeds. The range of these herbicides is continually being expanded, giving the farmer ever greater freedom in his work and cleaner land for his crops. The chemical industry has also produced many new and powerful insecticides and fungicides which give added protection to crops against pests and diseases. Here again the farmer, by their correct use, can be freed from many of the restrictions in his cropping which were previously essential if he were to obtain good yields.

Animal husbandry has received equally valuable help from the scientists in the post-war period. The methods of artificial insemination have been perfected so that the farmer can rely on this service and need no longer keep a bull. At first it was thought that the use of good bulls in the artificial insemination stations would result in an immediate marked increase in the average milk yield of our dairy herds. This assumption, at least for the milk recorded herds, did not prove to be well founded. An examination of the records showed that the pool of genetic material was well spread and that differences between the high and low yielding herds were not primarily genetic in origin but arose from variations in the standards of feeding and management. There was, however, evidence that a few bulls were capable of siring daughters, whose milk yields over a wide range of management levels, exceeded on average those of their dams. The selection of these bulls by progeny

testing has been made possible by the use of artificial insemination, which permits of a large number of daughter-dam comparisons in many different herds. Improvements in the treatment of disease have increased the average effective life of the dairy cow and greatly reduced mortality in sheep flocks. Pig breeding, rearing and fattening has been put on a firmer scientific basis although, in this branch of agriculture, much improvement is still possible. In no section of farming has science had a greater influence than in poultry keeping. Here university trained geneticists and nutrition chemists are to be found on the staffs of the large hatcheries and broiler plants and no one can hope to live in this world of intensive production and keen competition, without a knowledge of the scientific principles on which it is based.

The available labour, however, fell. The prisoners of war had all left by 1949 and the Women's Land Army by 1951. Regular labour fell from 537,000 in 1946 to 455,000 in 1956. At the same time the wages of agricultural workers were rising steeply; to meet the shortage and higher cost of labour the farmers turned to increased mechanisation. By 1954 there were 450,000 tractors in use compared with 200,000 in 1946. The combine harvester, with its associated drying plant, was finding its way on to more and more farms. Machines were coming on to the market, designed to perform many of the tasks which had so far been done by hand. The cow barn was being replaced by the milking parlour and hand milking was rapidly becoming a thing of the past.

This rapid expansion in mechanisation created its own problems. Farmers faced with high wages and shortage of men were being forced to spend capital they could often ill afford on machines. The problem for the smaller farmer was particularly difficult; the use which he could make of a machine might be quite inadequate to justify the interest and depreciation on the capital outlay, yet if he was to farm efficiently, with the labour available, he needed the machine. For a time after the war this difficulty was partially overcome by the machinery pools run by the War Agricultural Committees; when these were discontinued the only solutions remaining to the small farmer, apart from buying a machine, were the employment of a contractor or co-operation with a neighbour. To the farmer, who frequently did not really appreciate the heavy depreciation charges he was incurring—the new, often complicated machines, unlike the simple pre-war implements, depreciated rapidly even if they were unused—the contractor's charges seemed unduly high and co-operation with his neighbour unduly difficult; whichever alternative he took he was to varying degrees losing direct control of his farming operations. As a result many farms had an unjustifiable proportion of the available capital sunk in mechanical equipment, with a consequent heavy depreciation charge, which should have been, but was often not, provided for in cash reserves.

From 1946 onwards the new techniques introduced during the war, together with those which became available in the next decade, began to have a marked effect on production: yields of nearly all the main crops rose steeply. By 1956 cereal yields were exceeding those accepted as normal before 1946 by some 25 per cent. Potatoes were yielding, year by year, about 15 per cent more, although the effect of season makes this figure difficult to assess.

The production of the grasslands was greatly increased and was utilised more efficiently by controlled grazing and silage making. This was shown in the increased yields of the main products from grass: that of milk rose by over 40 per cent, beef and veal by nearly 60 per cent and mutton and lamb by just under 40 per cent. At the same time the output of pig meat rose by more than three times and that of eggs was almost doubled. The overall increase in production was such as to lift the net output of British agriculture to 156 per cent over the pre-war figure.

This increased output, achieved with a diminishing labour force, was still rising without the stimulus of military or economic pressure.

The agricultural revolution had thus far followed the expected pattern; the forces which caused it were no longer operative but the techniques which they had evoked were carrying farming forward to higher standards of efficiency. The output from our farms have under this impetus continued to rise and will go on doing so unless fresh economic forces put a brake on production.

The present average yield of wheat is around 25 cwt. to the acre, but many farmers expect to get an average over the years of not less than two tons. This is to some extent due to variations in soil and climate, but much of it is the result of

differences in the standard of husbandry. The cost per ton on the farms with the higher yields is undoubtedly less than on those with the lower; so many of the costs have to be incurred whether the crop is good or bad. It is only when the cost of extra cultivations, additional fertilisers and of harvesting the heavier crop, exceed the return on the increased yield, that the higher output per acre ceases to pay. Farmers who are getting the two-ton yields certainly believe that this is well within the profitable limit. They will strive for still higher yields and others will slowly copy them. With many farmers getting well above the average yield, there must be many others below. If these men adopt a higher standard of cropping the average yield of wheat throughout the country might easily rise to between 30 and 35 cwt. per acre; a position would then be reached where either a limitation must be imposed on the acreage grown or the support price adjusted so as to prevent a rise in the total subsidy. The second of these alternatives would in the end also result in a reduced acreage as the less efficient producers were forced to cut their wheat acreage or ceased to grow it altogether. The home grown production of wheat would then come from fewer acres, with a still higher average yield. Farmers who reduce their wheat land would seek fresh openings and try to enter other markets already suffering from over-production.

The same argument applies with equal force to milk production. This branch of farming has proved so efficient and profitable that output has risen beyond the demand for liquid milk, so that more must go to the lower priced manufacturing market. The result in the end must be either a restriction on output or a reduction in price. Here again, the less efficient farmer will be faced with the dilemma, should he go on producing milk at the lower, to him uneconomic, price or find some more profitable outlet for his activities.

British agriculture has reached a point of decision: it must either attempt to halt technical progress and rising output, relying on subsidies from the State for its future prosperity, or press forward ruthlessly, applying science to the full, and relying on the strength it so gains over the years, to face in the end fair competition from overseas producers, without the need for government support.

If it takes the first way, then it will always be subject to changes in political policy, to the limitation of production and to pressure to direct its output to suit the changing pattern of international agreements. The efficient producers will prosper, so long as prices are still fixed high enough to enable the less efficient to survive. If, however, political pressure results in cuts in subsidies, the farmer using technical knowledge to the full will still be able to farm profitably, but his less progressive neighbour will no longer be able to do so.

The resulting pattern would be that which inevitably follows depression in agriculture, a period of attrition. Farmers who find their profits disappearing do not easily go out of business, they restrict expenditure on the farm to a minimum and cut their own standard of living. On such farms there is little possibility of further technical progress and the level of farming could well go back to that existing between the wars. Unlike the inter-war years, however, there are now many more technically efficient producers, who would continue to farm profitably. These men would almost certainly follow the example of the relatively few prosperous farmers of the 'thirties and take over the land of their less successful neighbours when they finally gave up the struggle. Thus by a painful process of decay, the pattern of agriculture would be slowly altered, to one in which there were many more large farming units.

Should subsidies be continued but production restricted, then the efficient farmer will tend to suffer the more, because he depends on high production for low costs. Technical advances would be restricted to techniques which reduced costs without increasing output, an almost impossible condition. The result of any rationing of production must be a general depression in farming efficiency. Once the efficiency of farming can be seriously questioned there will inevitably be an irresistible demand for the removal of subsidies. The result of the removal of support from an inefficient agriculture would be disastrous. Only the strongest would survive and farming as a whole would return to the condition of the inter-war years.

If, however, the farming community decides to take the bolder course and press forward with the application of scientific techniques the way will be hard, but it will finally leave the farmers as free

from political pressure as any other industry and equally free to demand the right to protection against unfair competition. Many large-scale progressive farmers could today stand up to fair competition from abroad without any government support. For British agriculture to be on safe and solid ground the rest of the farming community must be brought up to this standard, whilst the pioneers go still further ahead. To achieve this, farming groups must be of a size which will permit the most effective use to be made of the available capital and allow economic mechanisation. They must have at their head men who are able to understand and interpret in practice the findings of the laboratory; who understand modern methods of management; who can apply scientific methods to save labour; who can keep and use cost accounts in the organisation of the business; and who have the time to think, read and direct.

Farming in Britain is in far too many individual units for scientifically efficient production. Of all those employed in agriculture, approximately one-third are in charge of an independent business of great complexity. Whilst farming methods remained static from generation to generation, it was sufficient, even in a complex business, to apply traditional methods; a man having learned these methods could succeed by hard work and thrift. Modern farming techniques, however, are changing almost from day to day and the farmer is called upon to make decisions which, in relation to his business, are of such importance that in industry they would be dealt with at the highest managerial levels. Is it not asking the impossible to assume that one man in every three employed in agriculture should have the mental ability, educational background and experience expected of only the few who form the senior managerial staff in industry? Can we expect these men to make wise decisions on matters such as the amount of mechanisation his farm can carry and the best form this should take, the optimum fertiliser dressings for his different fields and crops, the correct use of a complicated range of herbicides, and other agricultural chemicals, the planning of his buildings and farming operations to reduce labour to a minimum and perhaps, most important of all, the selection of suitable products which his land, the local climate and his fixed equipment will enable him to produce with the highest profit to himself? It may be argued that he has the help of the National Agricultural Advisory Service, but with one District Officer to every thousand farmers, individual help can only be available to the few who have the mental equipment to realise the value of this help and ask for it. On the other hand the farmer is the object of much high pressure salesmanship. There is no harm in this if he is capable of bringing sound and educated judgment to bear in relating what he is told to the complex needs of his own farm. What the salesman says about the value for example of a new machine may, so far as the machine is concerned, be correct, but the question is not what the machine will do, but whether, with the limited capital available, the machine is a good buy for the particular business. Decisions of this kind are too often made without the necessary careful calculation of the cost in interest, depreciation and maintenance, which are essential to a well-run business.

The farmer may also rely on the contractor for his spraying programme and for cultivations and harvesting. But the contractor must also live and his profit must be added to the basic cost of the operations and taken from the profit on the farm. It may be more profitable for a small farmer to employ a contractor, because either he has not the necessary specialised knowledge, or his farm cannot justify the interest and depreciation on the necessary machinery. Neither of these considerations would apply to a large farming group, where the specialist knowledge would be available and an amount of work sufficient to justify the machinery.

The maintenance of machinery also presents serious difficulties to the small farmer. Either he himself or his tractor driver has to carry out minor repairs, often with inadequate tools; major repairs have to go to an agricultural garage at relatively high cost and often with serious delays at important periods of farm work. As a result they often remain undone, with resulting serious damage to the machine. The large farming unit can afford its own fitter with a well-equipped shop and a regular schedule of repair and maintenance.

Farming is no longer an art or a way of life, but a highly scientific business and as such it calls for highly scientific management. This can only be achieved by the amalgamation of the many small units into larger holdings. Whether this is done by the voluntary joining together of smaller farmers or

by the gradual absorption of farms by a large farming company is of secondary importance provided the final result conforms to the same pattern. This pattern must ultimately be that of all successful industries in which a chief executive or group of executives is responsible for the running of the business with a highly trained technical staff. Such a system would place the control of farming in the hands of a relatively small number of the abler and better educated men engaged in agriculture. This would result in the wise and speedy application of new techniques, in rational decisions, based on factual records, as to the type and intensity of production and in the best use of the available capital. Whilst the able individual farmer might, by his intensive personal supervision, show a higher profit per acre or per man, the large farming units would undoubtedly show a better result over a large area than that obtained by a number of independent farmers of widely varying education and intelligence. Within the company there would be opportunity at the different levels for specialisation in branches such as mechanisation, stock management, or the use of fertilisers and agricultural chemicals. The young man would no longer see the farming ladder as years of austerity and hard physical labour whilst he scraped together enough capital to begin to farm a small acreage himself, followed by even greater austerity and longer hours of work whilst he built up his holding to a reasonable economic size. He would see his advancement coming by promotion within the larger organisation by the use of his brains and hard study and not by willingness to undertake long hours of dull routine toil.

Such a reorganisation of the industry would be painful and would involve many difficult sociological problems, but it would lead to a stable, healthy, independent and powerful British agriculture. It would involve specialisation in production and the optimum output from every man. The arable acreage might well fall as the yield per acre rose, freeing land where milk and beef could be produced on good grass with the minimum of labour. The ultimate pattern would, as in other industries, shape itself to meet demand, once the rigidity imposed by the large number of individual units, each tied by management, capital equipment and tradition, to a largely inflexible system of mixed farming had been removed. Most important of all it would allow the technical revolution in agriculture to proceed to its logical conclusion, a new stable scientific agriculture.

The farm would have to be as much a place of industry as the factory and efficient production the first consideration on farmland as on the workshop floor. The concept of the country as a playground for the city would have to go, except insofar as land was set aside for this purpose.

The agricultural revolution has lifted farming from a state of depression and unimportance to one of prosperity and major position in the national economy. The farmers have now to choose whether they should take action to reorganise the industry so that it may take advantage of every technical advance and over the next decade so improve its efficiency that, no matter which way the political wind may blow, it is strong and secure; or whether they will rely on political bargaining to maintain the present position and avoid reorganisation and further technical progress, with all that this implies in instability and the possibility of losing all they have won. Political memories are short and new generations are growing up who will forget the great debt the nation owed to the farmers in the war and think only of the immediate economic problems of the nation. When that day comes, the future of British farming will depend on how far the revolution brought about by the scientist and the engineer has been carried to completion.

WORLD COMMUNICATIONS*

By Sir GORDON RADLEY, K.C.B. *English Electric Co. Ltd.*

Introduction

During the post-war period rapid growth in the facilities for world communication using transoceanic telephone cables has appeared as technically possible. Just recently this has been followed by proposals for radio repeater stations in space satellites providing cheap and unlimited communication facilities on an even greater scale. The subject has more than engineering importance. World communication systems in the past have largely been provided by British enterprise. Cable and Wireless own 150,000 miles of submarine telegraph cable—more than half the world's total mileage; the widespread nature of our Colonial and Commonwealth interests provided an incentive to build such systems. But the great sums of money American governmental and private enterprise is now able to invest in space research and in launching satellites must constitute a threat to British retention of the world communication business.

The North Atlantic Route

Most of the major engineering advances giving promise of improved communication have first been tried out across the North Atlantic. Notable events were the attempts, about a century ago, to lay the first transoceanic submarine telegraph cable; Marconi's transmission of the first long-distance radio signals in 1901 and the completion of the first transoceanic submarine telephone cable system in 1956. The reason is the great concentration of traffic on this route. Excluding traffic to Europe, that from the United Kingdom to North America is between six and seven times that to all the rest of the world put together.

* Presidential Address delivered to Section G (Engineering) on August 31, 1961, at the Norwich Meeting of the British Association.

Frequency Bandwidth

Better communication facilities usually require the use of an ever-increasing frequency bandwidth. The first transatlantic telegraph cable transmitted telegraph messages at a speed of only 3 words per minute. It did so within a frequency bandwidth of about $1\frac{1}{2}$ c/s. The improved communication capacity of later transoceanic telegraph cables was made possible by their ability to transmit frequencies up to 100 c/s.

Speech requires the transmission of much higher frequencies. A modern transoceanic telephone cable will provide both-way paths for 80 telephone circuits, each path occupying a channel bandwidth of 3 kc/s.

Transmission of a television picture using the existing British standards of definition with its accompanying sound needs a 3·5 Mc/s channel. The higher standard of definition used by European television requires a bandwidth of nearly twice this.

The World Communication System in 1956

Prior to 1956 world telegraph communication was provided by submarine cable and radio; telephone communication could be provided on radio only.

Propagation of the radio signals depends on reflection from the ionosphere which is very dependent on sunspot activity and for 3 or 4 years out of a regular solar cycle of 11 years, the reliability and communication capacity of radio links may vary very considerably. Moreover, in the high-frequency (H.F.) band which is the most suitable for long-distance communication the

world total of frequency assignments between 4 and 10 Mc/s increased from 6658 in 1929 to 74,284 in 1959. It is quite clear that radio alone cannot satisfy the growing needs for world communication.

The Coming of Transoceanic Telephone Cables

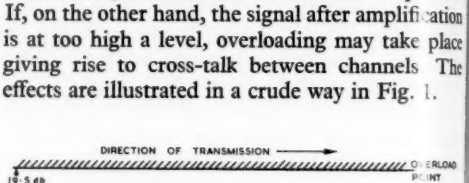
Long-distance telephony over submarine cables only became possible with the development of underwater electronic repeaters for the periodic amplification of signals at regular intervals along the cable. At the highest frequencies transmitted in a modern multi-circuit telephone cable, the power of the signals is reduced by nearly a half after they have travelled a mile and this loss is logarithmic. The first repeater—a very cumbrous and crude affair by modern standards—was not submerged until 1953. It is still pleasing to recall that the operation was conducted by the British Post Office.

The first transatlantic telephone cable was completed in 1956 as a tripartite venture between the American Telephone and Telegraph Company, the British Post Office and the Canadian Overseas Telecommunication Corporation. The section between Newfoundland and Nova Scotia, about 336 nautical miles, was of British design and construction. It has become the prototype for the cable being completed this summer between the United Kingdom and Canada (CANTAT), and will be the prototype of a number of planned systems, both British and American.

The distinguishing feature of the American designed part of the system between Newfoundland and Scotland—1950 nautical miles—was the use of two cables, one for each direction of transmission. This facilitated the design of the electronic repeater which is basically a one-way device. It did, in fact, become possible to build one-way repeaters for this cable in long, pressure-resisting, but flexible, steel housings which constituted no more than a bulge of just under 2¾ in. diameter in the cable.

In a system of this kind there must always be the fear of communication ceasing due to failure of one of the 303 valves and about 6000 other components in the submerged equipment. This led to a policy of conservative design with careful selection of components of well-proved types. Inspection during construction was searching and repetitive. The policy has been justified by the absence of repeater faults, although the cable has been cut on a number of occasions by fishing vessels near the shore ends.

In the first transoceanic telephone cable system each repeater annuls the loss in approximately 38 miles of cable preceding it. It must do so at all frequencies transmitted. The importance of getting the conjunction of cable and repeaters right is due to the fact that the system works between comparatively narrow margins. If the incoming signal to a repeater is at too low a power level the margin between the signal and the system noise is reduced. Signal and noise are amplified together and this may be cumulative at successive repeaters. If, on the other hand, the signal after amplification is at too high a level, overloading may take place giving rise to cross-talk between channels. The effects are illustrated in a crude way in Fig. 1.



SIGNAL LEVEL VARIATION ALONG TRANSATLANTIC CABLE

Fig. 1.

The problem arises, of course, because repeaters once laid are inaccessible and no practical means has been devised for adjusting their amplification from the shore end. The problem becomes greater as the length of the cable between landings and/or the number of repeaters in it increases.

An important development has been the introduction of TASI (Time Assignment Speech Interpolation) on the transatlantic cable circuits. TASI dispenses with a pair of channels—one for each direction of speaking—reserved for each telephone conversation in the ocean cable. By means of an elegant, electronic switching system for which the Bell Telephone Laboratories were responsible, TASI connects each fresh burst of conversation to any idle channel in the group. At the distant end a steering signal connects this

channel to the right listener. Provided the number of channels in the group is large enough, the number of conversations possible simultaneously is practically doubled.

The 'Round the World' Telephone Cable System

(i) *The Atlantic Section*

The cable laid during the summer between Scotland and Canada will form the first link in the projected Commonwealth round-the-world cable system. It is an entirely British achievement and is a distinct step forward in transoceanic cable technology. A single cable is used for both directions of speech transmission; the 'go' and 'return' channels being separated by the use of frequencies between 60 and 300 kc/s for speech in one direction and of frequencies between 360 and 608 kc/s in the other. At each repeater the two sets of channels are separated by electronic filters so that all channels pass uni-directionally through the amplifier.

When both-way transmission can be achieved within the communication capacity of a single cable, it usually provides a cheaper system. The necessary transmission of much higher frequencies for a given number of circuits means that the distance between points of amplification must be reduced and in the Canadian cable the repeaters are only 26 nautical miles apart. There are 89 under the water between Newfoundland and Scotland.

The filters which separate and subsequently re-combine the two directions of transmission add considerably to the number of components in each repeater and to the space which they occupy. This means that a comparatively large steel housing is required. The transfer of it from the ship to deep water has constituted a difficult problem. Unlike the flexible housings used for one-way repeaters, these large rigid housings cannot be made to follow the cable round a drum as part of the continuous laying process. But mechanical engineers have devised new types of laying machines to deal with this problem.

The Canadian project has made use for the first time in a major operation of a new type of deep-sea cable. Unlike traditional designs this is not armoured, the protection given by armour being, in fact, quite unnecessary in deep water. The cable is given strength by a high-tensile-steel core which is torsionally balanced. The cable has the advantage of being more easily handled, no more expensive, lighter and of lower attenuation for a given overall diameter. Armour, of course, is still used in shallow water near the shore ends.

(ii) *The Pacific Section*

The idea of a round-the-world cable of high traffic capacity began to take shape at a Conference of Commonwealth representatives in London in the summer of 1958. The Conference recommended a round-the-world cable system providing a measure of alternative routing in case of breakdown. When completed the system would provide telephone, telegraph, picture telegraph and telex facilities between the countries where it lands and to other countries by short radio spurs. The Conference anticipated that manufacture and installation of the system would be practicable within a period of not less than about 10 years without undue difficulty.

Planning for the Pacific section of the round-the-world cable is well advanced. This will provide transmission bands 240 kc/s in width in each direction over the sections Vancouver–Auckland–Sydney.

The cable to be used will be of the same construction as that just laid to Canada and the both-way repeaters will be similar in design to those used on the Canadian project. There will be 317 between Sydney and Vancouver.

A landing in the Hawaiian group of islands is planned; this will provide a convenient point for interchange of traffic between the Commonwealth system and an American East–West route across the Pacific.

One of the greatest difficulties in constructing a very long underwater section is the supply of power to the repeaters. Present practice is to energise them in series by a direct current fed along the centre conductor together with the high-frequency speech currents. A total driving voltage of about 4000 is required for the 51 repeaters in each of the first transatlantic cables between Newfoundland and Scotland. It is arranged so that the centre conductor of the cable and all the connected apparatus in the repeaters is 2000 v. positive to the sea at one end and equally negative at the other. Repeaters could certainly be adopted for 6000 V.

Fig. 2.—World wide communications provided via a system of low-orbiting satellites.

working, and even higher voltages might be practicable inside a rigid housing of the dimensions used for the Canadian project.

The use of transistors instead of valves would, of course, greatly simplify the power feeding problem. Very rapid progress is being made in transistor technology and it is possible that the first transoceanic cable with transistor amplifiers is not many years distant.

Transistor amplifiers will be necessary in a long cable to transmit television. The frequency bandwidth required for such transmission is such that the repeaters will have to be very close together and it would not be practicable to design a system, say, 2000 miles long, using valves. This leaves out of consideration any progress which the television engineer may make in reducing the bandwidth required for a picture of given quality and any special arrangements to reduce the bandwidth requirement, such as by using several minutes to transmit a few seconds of film.

The Artificial Satellite

The artificial satellite which communication engineers propose to use as a means of expanding world communications will act as a repeater station in space, having a line-of-sight path to the earth stations with which it communicates. Because radio communication will no longer depend on reflection from the ionosphere it will be possible to use that part of the radio spectrum between about 1000 and 10,000 Mc/s. This has a communication capacity several hundred times that of the H.F. band at present used.

Passive Satellites

The most elementary form of communication satellite consists of a simple reflector travelling round the earth at a height of a few thousand miles. President Eisenhower used a satellite of this kind to deliver a Christmas message in 1958. A more serious test of the feasibility of relaying radio signals over long distances by 'bouncing' them

from passive reflecting surfaces was made in 1960 when the United States National Aeronautics and Space Administration (NASA) put a 100 ft. diameter metallized plastic balloon into orbit at a height of about 1000 miles. This was known as the ECHO balloon and was used to reflect telegraph, telephone and facsimile signals transmitted between a NASA station in California and the Bell Telephone Laboratories at Holmdel, New Jersey.

Even when highly directional antennas are used on the ground, only a very small proportion of the energy radiated by the transmitter will hit a passive satellite and an even smaller part will be reflected back and dispersed over the earth's surface. Because of this, very high power transmitters would be needed to achieve communications using passive satellites at heights of interest. It is not only difficult to generate this high power at microwave frequencies but a transmitter of the power required would give rise to considerable interference. For this reason active satellites are more likely to be used for communication purposes. They will contain electronic repeaters which will amplify the received signals before re-transmitting them back to earth.

Active Satellites

The kinds of active satellite which have been most discussed are:

(1) Satellites in circular orbits at heights between 2000 and 6000 miles. Each will complete a circuit of the earth in 3 to 8 hours and appear to move fairly rapidly across the sky. A number will be required so that at least one is always visible to both terminal radio stations.

(2) Satellites in circular equatorial orbits at a height of 22,300 miles. At this height a satellite makes one rotation every 24 hours and therefore appears stationary relative to a point on the earth's surface.

An American proposal of the first kind would employ 50 satellites at a height of 3000 miles to provide world-wide communication as shown in Fig. 2. The satellites are divided into three sets in orbits making angles of 60° with each other. A variant of this, suggested in the United Kingdom, is for the use of satellites in elliptical orbits with perigrees 300 miles high and apogees

(reproduced by courtesy of Marconi's Wireless Telegraph Company Ltd).

Fig. 3.—Steerable Dish-Antenna

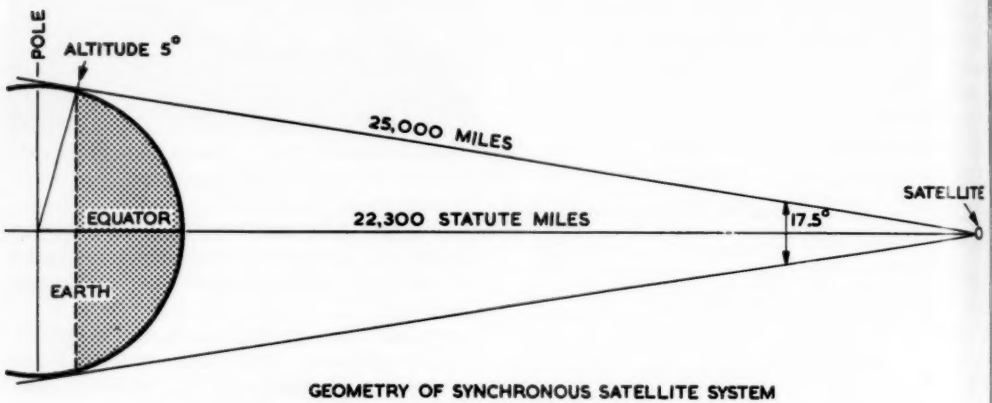
from 10,000 to 12,500 miles. Provided the orbits can be maintained in their relative angular positions, 12 satellites would provide complete global coverage.

All low-orbitting satellites, active or passive, require steerable transmitting and receiving antennas on the ground which can be continuously directed on to them. Dishes, 60 or 80 ft. in diameter, will probably be used. Fig. 3 is a photograph of a British antenna of this kind. In a commercial system these would have to be duplicated at each ground-station in order to prevent interruption of communications during the period when one satellite is beginning to pass out of view and another taking its place as the communication link. Because of the, desirably, very narrow beamwidth of the ground station steerable antenna, automatic tracking of the satellite will be necessary. This will be controlled by a signal returned from the satellite.

The second kind of proposal which makes use of satellites with an orbital period of 24-hours has a

number of obvious advantages. At this height a satellite will 'look-at' nearly half the earth's surface, as shown by Fig. 4, and only three such satellites would be required to provide for communication between any two points on the earth's surface.

Because the satellite will remain stationary relative to the transmitters and receivers with which it communicates, the design of the ground station equipment is simplified. On the other hand, the distance of about 45,000 miles which the radio signals have to traverse in a trip, ground–satellite–ground, introduces a delay of 240 milliseconds into their transmission, or about a half-second before a reply can be received. For the transmission of telegraphy, data, television and many other kinds of communication this does not matter. Communication engineers are as yet uncertain whether delays



GEOMETRY OF SYNCHRONOUS SATELLITE SYSTEM

Fig. 4.

of this order would be troublesome in a telephone conversation. They are appreciably longer than the delay of the order of 150 milliseconds which will be encountered on the longest wire line yet planned: the United Kingdom to Australia via trans-Atlantic submarine cable, thence across Canada by microwave and onwards by trans-Pacific submarine cable via New Zealand. But to reach Australia via a space system would require two 24-hour satellites with an intermediate ground station. This would bring the round trip delay to nearly one second which certainly would be serious.

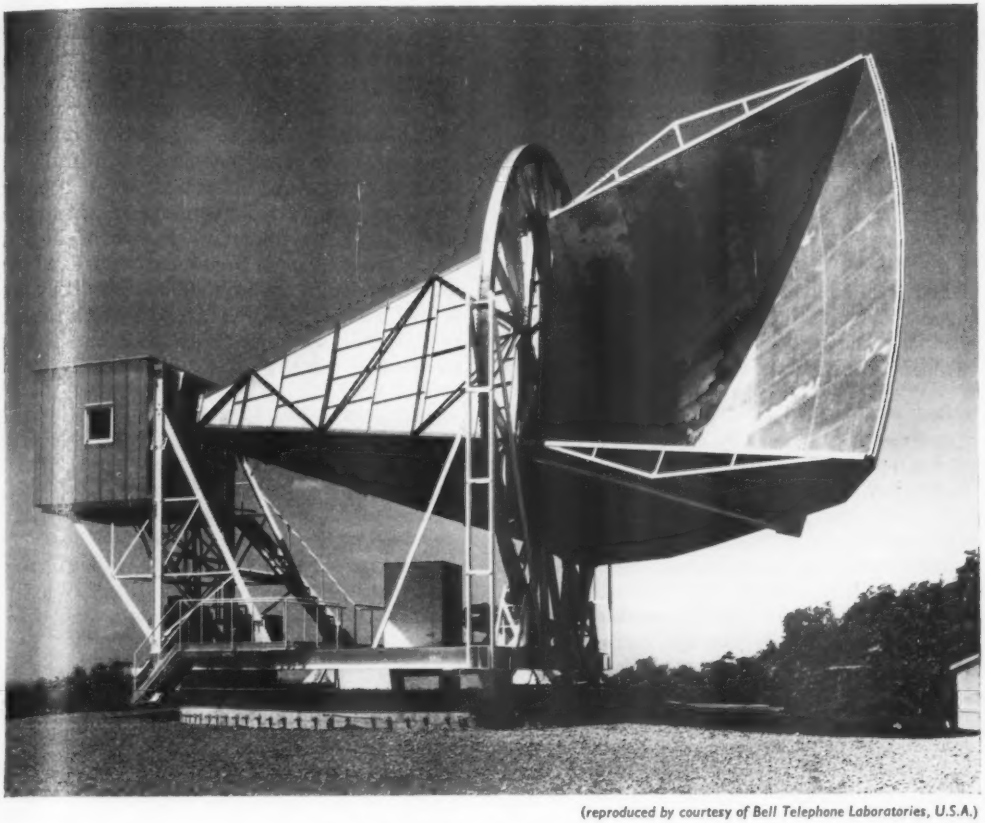
Satellite Power Sources

Power to operate the electronic equipment in an active satellite will be obtained initially from the sun although the long-term development of light-weight nuclear sources must not be ruled out. Much work has been done during the last 5 years on the development of the solar cell, principally by the Bell Telephone Laboratories in the United States. Although the cell, in its present form, is not yet satisfactory for long-term service in a satellite, it seems reasonable to plan on the assumption of its use in the future.

The solar cells may be supported on 'sails' at the sides of the satellite, extended after the satellite has settled in its orbit. They will have to provide an area of one or two square yards in order to generate enough power to operate the radio transmitter. During the time that a satellite is in the shadow of the earth, power will have to be supplied from storage batteries.

Satellite-to-Ground Transmission

Satellite communication systems will make use of frequencies in the same part of the spectrum as entirely ground based, radio-relay systems. But the distance between relay stations in a land system is usually about 40 miles compared with 4000 or much more to the satellite. Moreover, on land, highly directional transmitting and receiving aerials enable signals to be beamed from station to



(reproduced by courtesy of Bell Telephone Laboratories, U.S.A.)

Fig. 5.—Horn-Reflector Antenna.

station. Highly directional aerials are almost impossible to arrange on a satellite and, in order to make use of any directivity, it is neccessary to maintain attitude control of the satellite.

Taking both the increased distance and the lack of directivity together, the transmission loss between a communication satellite and its ground station may be 80 dB—100 million times on a relative power basis—greater than the loss between two adjacent stations in a land radio relay system.

The problem is not serious in the direction ground-to-satellite because high transmitting powers can be used, fed into large parabolic antennas directed on to the satellite. It is serious in the other direction because the power of the transmitter in the satellite is limited to 1 or 2 watts and the signals it sends out are dispersed over a very large part of the earth's surface.

Amplification of these weak signals by means of a device which itself has very low intrinsic noise is the nub of the problem. Because of the thermal agitation of its molecules, every element of an electrical circuit produces spontaneous unwanted noise signals at radio frequencies. It has become common to measure this noise in terms of the equivalent temperature of its source; for a conventional amplifier this may correspond to 3000° K. The invention of the 'maser' provided the engineer with low-noise amplifying devices of a new kind. Taking advantage of the principles of

quantum mechanics, a very weak incoming signal is able to trigger a great amount of power over a limited frequency range. The problem generally is to extend this range, but 'masers' have been constructed with a frequency coverage adequate for a satellite communications system. An effective noise temperature as low as 20° K. has been achieved using a maser receiver in conjunction with the large horn antenna shown in Fig. 5.

Modulation Methods

The economics of satellite communication suggest planning in terms of at least 600 two-way telephone channels, or one two-way television channel. It remains necessary to mention the way in which the messages will be impressed on the radio signal. Information theory tells us that by increasing the transmitted frequency band, it is possible to improve the signal-to-noise ratio without increasing transmitter power. Frequency-modulation is a technique frequently used for this purpose. Pulse-code modulation, in reality a method of processing information before applying it to any type of radio transmission, has many attractions. The important feature of both is their relative freedom from interference but fairly wide bandwidths are required and it is likely that at least 250 Mc/s will be needed by each satellite system for two-way communication on the scale envisaged.

PSYCHOLOGICAL FIELD STUDIES IN DEFINED POPULATIONS

By Dr. J. G. INGHAM, Dr. J. O. ROBINSON and Dr. K. RAWNSLEY

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It is not uncommon nowadays for people to be approached in their homes by various kinds of investigators and invited to participate in surveys. Sometimes, as in the case of the National Census, they are compelled by law to take part. Public opinion surveys and market research are perhaps the most widely known by the general public but there are many other fields of enquiry in which the most reasonable way of getting the necessary information is to go out into the community and interview people in their homes. The sensitive research worker often becomes acutely aware of the burden he is asking people to shoulder and tries to make it as light as possible by reducing his procedures so that they involve the minimum in time and effort by the participants. Nevertheless, he may have to ask people to give an hour or two of their time and to submit to some quite searching questions and tests. In terms of man hours, a person who takes part is making a contribution to research which is perhaps more valuable than a substantial financial contribution to a national research fund. A large majority of the population appears to be willing to make this contribution and a great responsibility falls upon the scientists who are doing the work to ensure that the time and effort is used to good purpose.

The purpose of this article is to discuss some of the reasons why we need to do this kind of research in studying problems in our own fields, psychiatry and psychology.

Ever since psychologists started to study human behaviour experimentally, they have had to rely on the co-operation of their fellow-men for the raw material of their research. It is true that some classic experiments have been done by the psychologist himself, acting both as experimenter and subject. Ebbinghaus, for instance, laid the foundations of our knowledge of learning in this way and made observations which have stood the scrutiny of many later investigators. However, it is impossible to rely entirely on observations of oneself, even if one is able to avoid the danger of self-deception, which is much greater in such a situation than when one is observing a stranger who knows nothing of the experimenter's preconceptions. In planning a psychological investigation, one of the most important decisions to be taken is how to obtain the people to be investigated.

Every psychological phenomenon can be said to be a result of two kinds of variations, those common to all individuals and those peculiar to one individual. Every human brain has the same general structure and operates according, one may presume, to the same general laws. This accounts for the fact that, within broad limits, human behaviour is remarkably predictable. Put anybody to learn a certain skill, say typewriting, and, as long as he expresses a willingness to learn, some improvement will occur. The course will be an irregular one (though it will tend to follow a known pattern) but it is impossible to say for any individual beforehand either how irregular, or how fast the improvement will be. If the object of an investigation is to determine general laws of learning to type, which apply to everyone, then almost anyone will serve initially to represent the whole of humanity. In practice one still has to show that the laws are in fact general laws, by repeating the experiments on a number of individuals chosen from a wide range of groups.

If on the other hand one is interested in aspects of behaviour which vary from one individual to another, say the rate of learning to type, then clearly the method by which individuals are chosen is of crucial importance. Having specified the 'population' of individuals for study, it may then be possible to obtain information about each

member or if the numbers are too large, a sample of the 'population' may be chosen which will represent the whole. One of us (K. R.) was associated with a project where an attempt was made to study all the members of a defined 'population'. By way of introduction, it should be mentioned that about three quarters of the patients in mental hospitals in England and Wales are chronic cases, i.e. they have been continuously in hospital for two years or more.

Until recently most of these patients were likely to remain in hospital for the rest of their lives. Now, however, many of them can be brought to a state of readiness for discharge. At this stage, the attitude of the outside community in general and of the patients' families in particular are important factors in influencing the transition from hospital to the outside world. The investigation was confined to three geographical areas; a mining valley, a rural area, and a small seaport with a total population of about 80,000. The main object was to determine the attitudes of relatives to all persons normally resident in the areas who were, at the time of the survey, in-patients in mental hospitals. It was also necessary to find something out about the patients themselves. The total number of patients, taking the three areas together was 230. This was the 'target' population and it was quite practicable in this instance to collect the information required for every member of the population. Much of the information concerning the patients themselves was culled from the hospital records and ratings of the patients' social capabilities were obtained from the doctor in charge of each case, the chief nursing officer, and the nurse in charge of the ward. It was found, for example, that 53 per cent of the patients were schizophrenics, that 67 per cent had been in hospital for two years or more and that 23 per cent had been in hospital for twenty years or more. There had been no contact whatsoever with relatives for one year or more in 20 per cent of the cases (except possibly by letters) in spite of the fact that for 96 per cent it proved possible to trace a family member living in the area. Of the patients lacking a visitor for a year or more, at least 65 per cent had a close relative (spouse, parent, child or sibling) in the area and a further 20 per cent had other relatives. This information is quite unambiguous. The population to which it refers has been clearly delineated and the relevant observations have been obtained from every member of it. It might be noted that we have also learnt something about the relatives of these patients, without actually observing any of them.

In order to find out more about the attitudes of members of the family to these patients, it was necessary to interview them in their homes. A set of rules was drawn up to govern the selection of relatives to be interviewed from the available family. Relatives were interviewed in a standard way using a schedule of questions. One matter explored in detail was the degree of willingness shown by relatives to provide a home for the patient in the event of recovery sufficient to warrant discharge. Judging by the statements of relatives, 60 per cent of the patients could rely upon their families to accommodate them on leaving hospital. The degree of willingness to provide a home was found to be inversely related to the patient's age in a striking way. There was also a reduction of willingness with increasing length of stay in hospital, though this was relatively slight for patients less than 65 years old. None of the patients who have been in hospital for 10 years or more and who are over 65 can count on the family providing a home.

Patients visited by their relatives during the past year are much more favoured in their prospects of finding a home than the unvisited group. However, 24 per cent of those patients not visited for a year or more have relatives who state that they would be willing to receive them.

Generally, one is interested in larger populations. When it is impossible to make observations on each member, it is necessary to take a sample and to infer from the information thus obtained something about the population as a whole. In order to make such an inference, the sample has to be selected according to very definite rules. The object of these rules is to ensure that one knows the relative probabilities of entering the sample for any individuals in the population. The simplest rule to adopt is to select the sample at random, that is in such a way that each member of the population has an equal chance of appearing. There are other ways of achieving the desired result but the essential point is that at some stage in the selection a process of mechanical randomisation must be introduced.

Although random sampling is desirable whenever

one wishes to make inferences about a population, the practical problems involved are usually very great and psychologists tend to content themselves with some less satisfactory alternatives in which ease of access is substituted for randomisation. One never knows exactly what effect such a procedure has but it may distort the results considerably. As an example, let us consider an intelligence test which is widely used for individual assessment of intellectual ability in adults, the Wechsler Adult Intelligence Scale.[1] The purpose of an intelligence test is to enable us to say how a person stands in intellectual ability, in relation to the population as a whole. We therefore need to know the distribution of scores in the general population and the business of standardising a test consists of giving it to a sample from which inferences can be drawn concerning the population characteristics. As we have already seen, the selection of such a sample should involve a process of randomisation. Wechsler's sample, however, does not appear to have been selected in this way. He used the method of quota sampling, in which the relative proportions of people of each age, sex, geographical region, urban and rural residence, race, occupation and education were predetermined so that they would be the same as the proportions known to exist in the population. His assistants were then told what age, sex, etc., each of their examinees was to be, but apart from this restriction it appears that they were free to select whom they chose. Wechsler admits that this probably introduced a bias, which he presumed to be towards the more intelligent. Thus we are left with a situation in which the apparent intelligence of everyone who does this test might be underestimated but we do not know for certain if this is so, nor by how much. In fairness, it should be said that the magnitude of the task would have been greatly increased by introducing a process of randomisation and that a compromise was probably necessary. The test is a useful one in spite of the criticism but users have to take its possible bias into account.

Sampling is important, also, when we want to compare groups. To take an absurd example; if one went into a housing estate at 11 a.m. on a weekday and wandered around knocking at doors here and there, quite haphazardly, it may well be found that nearly all the respondents were women between the ages of twenty and sixty-five. If one proceeded to draw conclusions from this sample about the age and sex distribution of the estate's population when compared with the population at large, the results would be curious. Of course, sex and age are things that we know about. This is what makes the example seem absurd. But suppose we wish to know about the distribution of some aspect of personality as revealed by a psychological test. We may know, or suspect, that scores on the test are affected by age, sex and perhaps one or two other things like education and occupation. Knowing how these things are distributed in the population we wish to know about, we can easily arrange things so that the sample is, in these respects, like the population. This is the method of quota sampling mentioned before, and may still be done by haphazard knocking at doors. The only alteration required is a careful choice of times (some of the visits would have to be done when the men were home from work) and some preliminary questions to get the information about age, occupation, etc. Then all we have to do is to test those individuals needed to ensure that we have the right numbers of each sex, age, occupation group, etc. We shall then know that, in certain respects, the sample is like the population. But it will still tend to contain a greater proportion of the stay-at-homes and those who are most willing to answer the door. Characteristics like this are likely to be associated with personality and by taking the results as typical of the population as a whole we are laying ourselves open to serious error. We could only be sure about the accuracy of our inferences about the population if we knew that all individuals of the same age, sex, etc., had the same chance of being chosen for the sample. The population of interest may not be the whole population of an area, of course, but may be restricted in some way. We must then sample at random from the restricted population.

To proceed now to the second main point. It has been recognised for a long time that one of the most important things about a psychological test is that it must be given under standard conditions. That is, if the results are to be used to compare one individual with another, they must be obtained under conditions which do not vary from one individual to another. This is fairly easily achieved. Identical test materials must be used in all cases,

precisely the same instructions should be given, precautions should be taken to see that the instructions are fully understood, the room should be free from distractions (unless a standard distraction is part of the test) and so on. Little attention, however, has been paid to the effects which might be produced by the different attitudes which people have towards the tests. It is usually easy enough to detect extreme cases. The person who regards the whole thing as absurd and therefore gives ridiculous answers is an obvious example. There must be many cases which are less obvious.

There is evidence that the problem may be particularly acute in making personality assessments by means of questionnaires. This was shown in an investigation by Dr. Alastair Heron.[2] He gave a two-part questionnaire to a group of applicants for jobs in a public undertaking. One part was designed to assess emotional maladjustment and the other sociability. Half the applicants were given the questionnaire as a part of the selection procedure, though the results were not used for this purpose. The other half were told the results of the selection process before being asked to complete the questionnaire as part of a research project. The results showed that the people seen during the selection procedure showed considerably less emotional maladjustment according to their answers, than the people seen during research conditions. This shows that responses to a questionnaire can be modified by changes in the circumstances in which it is administered. When groups are tested under different circumstances, comparisons between their responses might be very misleading.

The same thing was shown in a study on schoolchildren by Thorpe and James.[3] They used a number of tests which previous work had shown to reveal differences between emotionally disturbed and normal children. They divided their emotionally disturbed group into two. One half was tested in the clinic and the other half in school, with nothing to cause the children to associate the tests with the clinic visits. The normal children, of course, were also tested at school. In this case, it was shown that the emotionally disturbed children tested at school tended on the whole to show less indication of emotional disturbance on the tests than those tested in the clinic. The tests which revealed this most clearly were those of the questionnaire type, though others were affected as well. All this work throws doubt upon comparisons between neurotic and normal people when the general situation in which the tests are given is not adequately controlled.

To summarise the main points made so far; in any investigation in which we wish to make inferences about the distribution of test scores in an existing population, it is desirable to use an appropriate sampling procedure which at some stage should involve a random choice. Secondly, if we wish to make comparisons between two or more groups, we should make sure that the groups are tested under identical circumstances. This applies not only to the immediate testing environment but also to the wider context in which the people are asked to do the tests.

When the 'target' population is defined geographically and comprises all the inhabitants of an area, then one convenient way of studying the appropriate sample, once it has been selected, is to visit people at home. The alternative is to transport them all to the same centre. This has the advantage of making possible a greater standardisation of the testing situation but it may increase considerably the inconvenience caused to participants. Also, however one controls the immediate testing environment, different people respond in a variety of ways to unusual situations and this is difficult to control. It may, in fact, introduce an undesirable source of error which can be lessened by testing people in the familiar surroundings of their own homes.

There are two common kinds of psychological studies of individual differences which involve considerations of the sort we have been discussing. One is a method of validating psychological tests, that is, of showing that they measure what they purport to measure. It is done by trying the tests out on criterion groups, chosen to represent different extremes of whatever it is that we wish to measure. For example, a test of neuroticism would be given to a group of people known to be neurotic and to a normal group to see how successfully it distinguished between the two groups. What do we mean by 'known to be neurotic'? A common sense view is that we recognise a neurotic individual by the way he behaves or feels, but to specify the kind of behaviour or feeling involved is not easy. We

could take those patients who go to the doctor and later find themselves on a psychiatrist's list with the name 'neurotic' attached to them. But, if we take a sample of neurotic patients from an out-patient clinic in a hospital we shall have a group which is selected, not only by virtue of showing a certain kind of behaviour or experiencing some sort of emotional distress, but also, among other things, because they live in a particular geographical area, belong to a certain occupational group, or live in a particular kind of social environment. Any other group with which we wish to compare them, to show up differences in our test of neuroticism, should possess similar characteristics in all respects other than neuroticism, as long as there is any likelihood that these characteristics might influence the test scores.

The second kind of enquiry is one in which we wish to compare patients suffering from a certain illness with other patients or normal individuals, perhaps in order to test some hypothesis concerning the nature of the illness. Consider, for example, the kind of illness which is often referred to as 'psychosomatic': disorders of body functions which many people attribute to emotional causes. Two 'psychosomatic' hypotheses may be tenable for any of these illnesses and the failure to recognise them as separate possibilities has sometimes led to confusion. One hypothesis is that psychological events during the patient's life-history have contributed to the cause of the illness. For example, the suggestion has been made that a bereavement or some other loss of a close loving relationship renders people more likely to contract tuberculosis.[4] The other hypothesis is that people with certain personality characteristics are more likely to develop the illness. The first hypothesis should be tested by observing events in the patient's life-history, the second by devising means of assessing personality and applying them to patients and suitable controls. In both cases it is necessary to compare a group of patients suffering from the illness concerned, with another group chosen from the general population not suffering from the illness but otherwise comparable with the patients. It is clear that we have here a problem which necessitates both proper sampling and standardisation of the whole test situation. It would not, for instance, be satisfactory to compare patients tested *in clinics* with controls tested *at home*.

An investigation of a problem of this kind, which also introduced questions of test validity and the use of criterion groups was done by one of the writers (J. O. R.) and may be quoted as an example. We are indebted to Prof. Cochrane of the Pneumoconiosis Research Unit whose collaboration has made this work possible.

Prof. Cochrane and his colleagues have for many years been studying the prevalence of a number of chronic illnesses amongst the populations of two carefully defined areas. One of these is a mining valley, the Rhondda Fach or Little Rhondda, with a population of about 25,000.

A complete census has been taken of each of these areas, an essential first and very laborious step in obtaining a random sample. The populations of both areas have been very carefully introduced to the idea of large-scale medical surveys, over a number of years. This is an important point and suggests that one could not necessarily expect to find the same high degree of co-operation from other communities, who have not had this period of preparation beforehand. Because of the facilities afforded us by the Pneumoconiosis Research Unit we have been able to take advantage of all this work and undertake a study which took account of both the problems which we have been discussing.

Our colleagues were interested in a possible relationship between blood pressure and personality, particularly emotional instability, in the general population. It was necessary to have a satisfactory method of assessing emotional instability and the following steps were taken to see whether the tests used for this purpose actually did the job they were supposed to do. It seemed reasonable to take patients attending psychiatric clinics and hospitals and suffering from the various forms of neurosis as extreme examples of the emotionally unstable. We looked through the literature and found a number of tests which had already been given to groups of normal and neurotic people and found to show statistically significant differences between the groups. There were three reasons why we felt it was necessary to check these results independently. The first was that the population we were using (from the Rhondda Fach) was very different in many respects from those in which the previous studies had been conducted. It would be unwise to assume that the results would be similar

in such different populations particularly when personality tests were involved. Secondly, we felt that the previous studies had not taken sufficient account of the possibility that test performance was affected by the different situations in which normal and neurotic individuals were examined. Thirdly, we felt that we were in a position to find a more satisfactory solution to the problem of sampling than the previous workers.

The tests required the minimum of equipment and could easily be done in a person's home. The Maudsley Personality Inventory is a questionnaire about such things as moodiness, the ability to concentrate and sociability. There were also a number of similar tests involving sources of annoyance, likes and dislikes, worries and food dislikes. There was a body sway test (a measure of the amount of sway whilst standing for 30 seconds with closed eyes) and a manual dexterity test. Finally there were some questions about feelings in various situations which might be expected to be stressful. The testing procedure took about an hour.

These tests were given to a sample of people within a certain age range, living in the valley. As it was a close approximation to a random sample, we could make inferences about the distributions of scores in the entire population of the valley in the specified age range. The criterion of whether the tests were good tests of emotional instability was whether they were able to distinguish patients suffering from neurosis from the general population. A group of such patients, from the clinic serving the valley and other similar valleys in the area was tested. Only patients from mining valleys were included but they were not all from the same valley. It would have taken too long to accumulate enough patients from one valley and we felt that the population of the area as a whole was sufficiently homogeneous to ensure that failure to control area precisely would not introduce a serious error. The random sample comprised 167 people and there were 56 patients. To ensure that people's attitudes towards the tests were as well controlled as possible, they were all seen in their homes and given the same account of the project, i.e. that it was entirely for research purposes.

The question to be decided was whether, on each test, the distribution of patients' scores was sufficiently unlike that of the random sample to justify a conclusion that they really were different and that it was not merely a chance variation. Analysis of variance showed a significant difference for five of the eight tests which had shown significant differences in previous investigations. The tests which failed to reveal significant differences in our investigation were behaviour tests. Most of the paper and pencil tests differentiated significantly between the groups.

For the purpose of the main investigation to see if emotional instability was related to blood pressure) we needed a single index, not ust a series of test results. For this purpose a discri inant function was calculated (the combination f test scores which gave the best discrimination be ween the groups). This we called emotional inst bility and some measure of its success is the fact hat it correctly classified about 65–70 per cent f the cases. In other words, if the tests had been a plied to a mixture of the groups we should have been able to put them into their appropriate cate gories with 30–35 per cent misclassifications. It wo ld, of course, be expected to be less successful i now applied to a new group. This is an example of the use of field studies in establishing the validity of psychological tests. The chief advantage of such a study for this purpose lies in the fact that it enables one to get an unbiased estimate of the distribution of test scores in the population concerned.

The blood pressure of the random group had already been measured by Dr. W. E. Miall of the Pneumoconiosis Research Unit.[5] When blood pressures and emotional instability scores were examined no significant relationship was found in most age groups, but the 41–50 age group was a conspicuous exception. It is particularly interesting that a significant correlation should occur in this age group where problems of hypertension generally begin to gain importance. However, the correlation is based upon a small number of observations and requires confirmation.

Another aspect of the results also deserves attention. When the emotional instability scores of the clinic hypertensives were compared with those of the random group they were found to be very significantly higher (Fig. 1). Such a difference would be a necessary consequence of a high correlation at all ages between blood pressure and emotional instability; a group selected for high

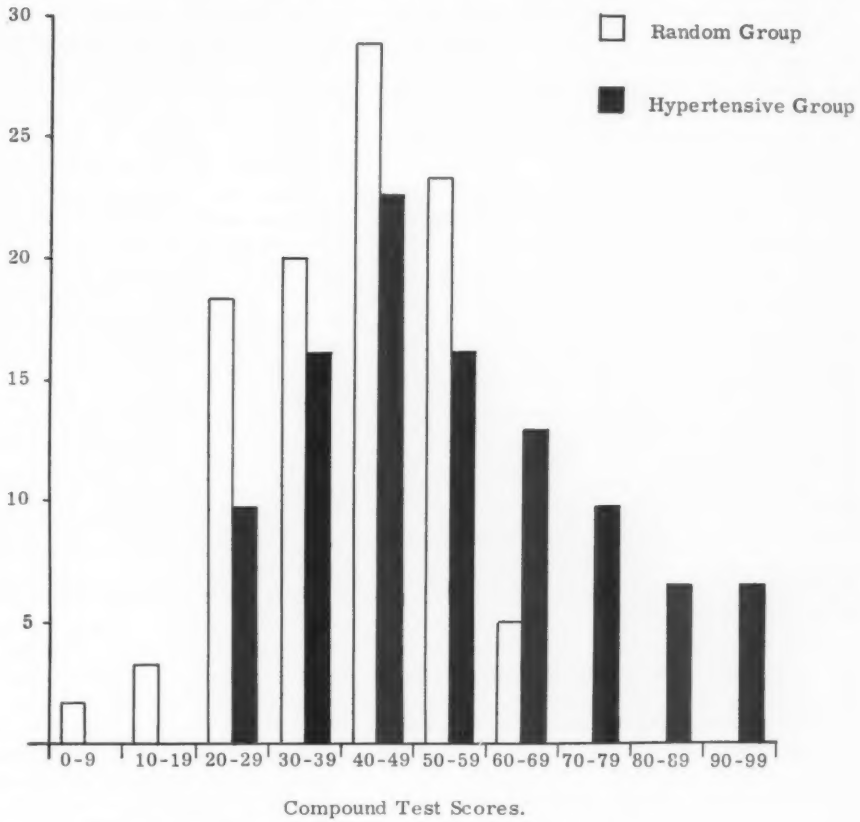

Fig. 1.—Comparison of frequencies of compound test scores.

blood pressure would also have high emotional instability scores. But since there is a significant correlation only in the 41–50 age group the question arises as to whether the difference in emotional instability scores of the two groups can be attributed wholly to the correlation or not.

Certainly the clinic hypertensives were almost all over 40 so that a large proportion of them fell within the age group where a correlation existed. But those over 50, where the random group showed a much smaller correlation, actually had a higher emotional instability score than those between 41 and 50.

Further, it is possible to select from the random sample aged over 40 a group whose blood pressures have the same lower limit as the clinic hypertensives. The mean blood pressure of this group is somewhat lower than that of the clinic hypertensive group but the mean emotional instability score is *very much* lower. When a correction is made for the difference in blood pressure the mean emotional instability scores still differ, though not significantly. The possibility cannot be dismissed, therefore, that some other factor, in addition to the correlation, determines the high emotional instability scores of the clinic hypertensives.

Space here does not allow detailed consideration of the various possible alternative explanations of the high scores of the clinic hypertensives. Perhaps the most important possibilities are:

1. That, of those individuals who have various vague symptoms, only the more emotionally unstable consult a doctor.
2. Emotionally unstable individuals tend in any case to consult a doctor more often and therefore any incidental sign (such as high blood pressure) will be discovered.
3. The test scores are affected somehow, either by treatment or by attendance at hospital with its concomitant anxieties.

This research illustrates the difficulties that arise from taking a group of hospital or clinic patients as typical of individuals suffering from a specified disorder, when the disorder is one which produces symptoms of a mild and vague nature. If the random sample had not been studied, it may well have been concluded that blood pressure and emotional instability were associated. In fact, although the clinic hypertensives certainly appeared to be emotionally unstable when their test results were compared with those of the general population, it is by no means certain that, in general, people with high blood pressures tend to be emotionally unstable.

The approach outlined in this paper to the study of social and psychological aspects of illness is gaining in popularity. Social scientists including psychologists, sociologists and anthropologists are joining forces with doctors in studies of disease outside the confines of clinics, hospitals and laboratories. To the extent that such enquiries provide a more balanced and complete picture of any given morbid condition they are a necessary complement to intensive clinical, laboratory and pathological investigation. They break new ground in their effort to identify, define and measure social and psychological factors linked with the cause, progress, prevention and resolution of disease.

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FROM GALTON TO CROWTHER*

By Prof. GEORGE SETH *Department of Psychology, The Queen's University of Belfast*

Fifty years ago, in January 1911, at the age of eighty-nine, Sir Francis Galton died. He was the last of the great Victorian scientists and the one, above all others, who saw clearly the significance for the study of man in society of the Darwinian concept of evolution. Galton left school—in the present context the point has an almost ironical significance—at the age of fifteen, in the year when Queen Victoria came to the throne. Thereafter he had two spells of never-to-be-completed medical training at Birmingham and London, with three years of mathematical work in the middle, that petered out in a poll degree at Cambridge in 1843. Not, on the face of it, an auspicious start. It is hardly surprising that Galton formed a poor opinion of the effect of education 'on a mind of the highest order'.

> A youth of the highest ability [he wrote years later] is almost independent of ordinary school education. He does not want a master continually at his elbow to explain difficulties and select suitable lessons. On the contrary, he is receptive at every pore. He learns from passing hints, with a quickness and thoroughness that others cannot comprehend. . . . The best care that a master can take of such a boy is to leave him alone, just directing a little here and there, and checking desultory tendencies.

It was with this far from systematic educational background, owing nothing to the great Public Schools or the Sixth Form, that Galton found himself embarked upon one of the most original and effectively creative scientific careers of the nineteenth century. His contributions to the separate fields of geography, anthropology (including anthropometry), psychology, and statistical theory and technique have already been discussed at this meeting. It is fitting, however, that we should remember also the contribution that he made to the British Association itself. He seems first to have attended the meetings of this Association when he was seventeen, and thereafter his name appears seventeen times in the Reports of the Association, on three of these occasions as sectional, or as it was then called, departmental President—once in Geography, and twice in Anthropology. He was a member of the Council of the Association, for four years its General Secretary, and twice he was offered the Presidency. In a period that must surely have been the hey-day of the learned societies, he contributed to well over a dozen of them, sometimes many times, and on no less than fourteen occasions to the Royal Society alone. He held medals awarded by four of them, and three—the Gold Medal, the Darwin, and the Copley Medal—from the Royal Society of which he was a Fellow. It is a spectacular record.

In the development of the biologically oriented, quantitative psychology of the twentieth century, Galton's influence was especially powerful, and that more particularly in the branch of the subject that we have come to call psychometrics. At the outset in England it rested squarely upon the development of the statistical tools which Galton, inspired by Quetelet, was first to utilise, and it is concerned with the facts of individual differences which, when he had assimilated Darwin's work, gave a new long-term direction and purpose to Galton's thinking. Galton did not see himself as writing a psychology like Herbert Spencer; he had no ambitions in that direction. One aspect or another of nature, and later of human nature, aroused his curiosity, stimulated the kind of question that for the research scientist becomes a kind of cerebral itch until he has achieved an

* Presidential Address delivered to Section J (Psychology) on September 1, 1961, at the Norwich Meeting of the British Association.

answer that for the time being satisfies him. So it was with the concept of heredity, upon which Darwin's book had cast a disconcerting light. For half a century Galton lived with the problems of psychological inheritance, worried over them, experimented upon them—by the technique of blood transfusion applied to rabbits—and, with some surprising blind spots, theorised and propagandised about them. With an almost naïve biological evolutionism, he emphasised from the outset that psychological, as well as physical, characteristics must obey the laws of heredity. 'I propose to show', he said in 1869, 'that a man's natural abilities are derived by inheritance, under exactly the same limitations as are the form and physical features of the whole organic world.' Hence his studies of the family trees of the outstanding figures of various periods down to his own time—the judges, the scientists, the divines, and so on, and hence too his abiding concern about the supply of really high ability in society, indeed, in the world.

Galton seems, for all his realism and geniality, to have been genuinely worried about the approaching crisis of human psychological resources, like the economist before the threat of a slump.

> We, too, the foremost labourers in creating this civilisation, are beginning to show ourselves incapable of keeping pace with our own work. The needs of centralisation, communication, and culture (and we may add, in 1961, of technological advance) call for more brains and mental stamina than the average of our race possess. We are in crying want for a greater fund of ability in all stations of life, for neither the classes of statesmen, philosophers, artisans, nor labourers are up to the modern complexity of their several professions. An extended civilisation like ours comprises more interests than the ordinary statesmen or philosophers of our present race are capable of dealing with, and it exacts more intelligent work than our ordinary artisans and labourers are capable of performing. Our race is overweighted, and appears likely to be drudged into degeneracy by demands that exceed its powers.

This jeremiad from *Hereditary Genius* (1869) echoes down the century, although the balance of the emphasis shifts, in Sir Geoffrey Crowther's recent address at the London School of Economics.

> I am not concerned [Crowther said] with whether (as a nation) we are a First Class Power or a second. I am concerned with whether we can keep our people employed and fed. Our natural resources, which gave us such a fabulous start over everyone else, are disappearing. So is our inside track to so many of the richest markets of the world. We still have a formidable accumulation of capital both physical and financial, but we are doing less than many other countries to maintain it. More and more we must live on our wits, more and more our position will approximate to that of countries like Switzerland, Denmark, and Sweden, which maintain high standards of living by the daily exercise of superior knowledge and intelligence. More and more, this is the only advantage that we too shall have. Shall we be able to retain it if our system of education is one that is based on tight restriction of numbers and on the rigid maintenance of a hierarchy of intellectual rank If you can believe that, then, as the Duke of Wellington said, you can believe anything.

Against this background I would invite your attention to an issue that has only recently become a matter of some general concern in this country, and one that has evoked somewhat different responses from different sections of the articulate community. It is the problem of the abler minority, and still more of the gifted few—who will still be a minority however generous or politically biased our estimate of their numbers may be, and whatever sort of schools we provide for them. The psychological interest of the problem is great, as Galton saw, but it has been the concern of too few psychologists in Great Britain, despite the active involvement of some of them in the process of educational 'selection', which ought rather perhaps to be regarded as a means of educational 'distribution'. The late Sir Godfrey Thomson is, I think, the only psychologist of standing who admitted as a principal motive for his own effort to improve our testing instruments the highly personal fact that his own distinguished career was the long-term outcome of his (in the context of the time) competitive achievement of grammar school entrance. It is a social problem of immediate and topical concern because of the increasing, if still inadequately fulfilled, extension of educational opportunity since 1944.

The city of Norwich is, of its own volition, caught up in the academic aspect of the problem, which arises from the widely accepted official policy, that the next decade should see a further major expansion of the university population of the United Kingdom, continuing the not entirely deliberate expansion of the post-war period that has just passed. Norwich is only one of seven new

universities for which the plans are now in varying stages of gestation or delivery, and it is important that we should examine this educational development. At its lowest level, it is the taxpayer's problem—I am told that it costs between £10,000 and £20,000 to train a doctor. On a higher plane, it depends upon a continuing revolution in our social attitudes which Raymond Williams puts in one sentence when he says that 'we should regard human learning in a genuinely open way, as the most valuable real resource we have, and therefore as something which we should have to produce a special argument to limit rather than a special argument to extend'.

The first of Galton's thinking was biological; his enquiries were restricted to the superlatively pre-eminent 'one in four thousand'; his prescription was therefore, eugenic in character.

> By natural ability [he meant] those qualities of intellect and disposition, which urge and qualify a man to perform those acts that lead to reputation, I do not mean capacity without zeal, nor zeal without capacity, nor even a combination of both of them, without an adequate power of doing a very great deal of very laborious work. . . . It follows that the men who achieve eminence, and those who are naturally capable, are to a large extent identical.

Convinced that this complex of ability, energy, and drive is all alike inherited, his later eugenic formulations represent, as one of his biographers has said, 'the first tentative efforts of a kindly man to apply to humanity the harsh lessons of biology as then understood'.

> From fairest creatures we desire increase,
> That thereby Beauty's rose might never die.

He had

> no patience with the hypothesis, occasionally expressed and often implied, especially in tales written to teach children to be good, that babies are born pretty much alike, and that the sole agencies in creating differences between boy and boy, and man and man, are steady application and moral effort. It is in the most unqualified manner that I object to pretensions of natural equality.

Hence, hope for the future lay only in a differential birth-rate, fostered by suitable public provision and reward, which would ensure that the balance would tip where he wanted it to do so.

Galton had been driven to

> the undeniable, but unexpected conclusion, that eminently gifted men are raised as much above mediocrity as idiots are depressed below it, a fact that is calculated to considerably enlarge our ideas of the enormous differences of intellectual gifts between man and man.

The educators also, as universal compulsory schooling became effective, should have been equally alive to the facts of individual differences. But they were the victims of a kind of psychic hemianopia in which their vision was restricted to the sub-average section of the population, with whom Galton had 'not cared to occupy himself much' though 'they would be an interesting study'.

There appear to have been several, sometimes contradictory, reasons why we should at the beginning have faced the facts of individual differences at the lower end of the scale only. The tough-minded optimism of *laissez-faire* could believe that genius, in spite of obstacles, would out, and Galton was on this side the child of his age.

> I believe that, if the eminent men of any period had been 'changelings' when babies, a very fair proportion of those who survived and retained their health up to fifty years of age would, notwithstanding their altered circumstances, have equally risen to eminence.

For some examples of extreme 'genius' this has been true; and it may be that there are few mute inglorious Miltons. But if we take a wider sweep than Galton's, if we consider the group of abler children, two or even one and a half standard deviations above the mean, we may find that they are more readily submerged or suppressed by adverse circumstance, and that the range of adverse circumstance is wider and its character less obvious than we had supposed.

Secondly, the handicapped are noticed because, both actually and potentially they constitute a greater nuisance. Especially in an urban and mechanised civilisation the illiterate and the untrained are troublesome. Something must be done about them, and humanitarian considerations insist at least upon some mitigation of *laissez-faire*. But perhaps underlying our high principles and our one-sided action, there are subtler elements of prejudiced thinking. Even psychologists, as Denys Harding has pointed out,

> have . . . concentrated their studies on those (from the albino rat to the academic student guinea-pig)

who are in one way or another of lower status than themselves in some hierarchy . . . it remains a limitation that psychologists have been able to give so little direct attention to those more distinguished than themselves, and to the qualities that make for excellence in civilised directions.

I hope I need not apologise for this excursion into problems of value. They cannot be evaded if we recognise that Galton's biological problems and his eugenic prescription have been given in our time a sociological twist, and treatment has shifted from the eugenics laboratory to the schools and universities. Galton's views about the supply of brains, the community holdings in terms of ability, were strongly hereditarian, and few psychologists would run to the environmentalist extreme. But hereditarian and environmentalist alike 'can wholeheartedly join . . . in the demand that more and better educational opportunity be provided for every child'. Our views about the inheritance of ability have been tempered somewhat in 1961, but we may not 'expect that equalisation of opportunity will result in equality of achievement'. (Terman).

Galton arrived at his view of the nature and inheritance of high ability by way of an inductive study of historical characters by means of biographical material. Noel Annan has amplified it in his entertaining account of the formation of the intellectual élite of the nineteenth century as a result of the intermarriages of a particular group of middle-class families. These and similar studies have demonstrated how certain small 'connections' have produced eminent characters out of all proportion in their size. But the picture has splashed and become blurred and indistinct in the mid-twentieth-century transition. Behind the Crowther Report of the Advisory Council for Education is the uncomfortable sense that the High Intelligentsia of England perhaps require some support and reinforcement. 'Of the hundreds who aspire, eighties perish, nineties tire', but we are not restricted to one in four thousand of the generality, nor even to the highly selected few who win open awards to the colleges of Oxbridge. Moreover the psychological test, the scientific efficacy of which has been unfairly clouded by its practical utility, has made possible a kind of Galton-in-reverse. Instead of working backward from the adult to his formative period, Lewis Terman could locate his gifted children, the 'geniuses' of their age-groups, could obtain contemporaneous data about them, and follow them through to adult life.

The basic clause of the Education Act of 1944, the age-ability-and-aptitude clause, with its audible psychological overtones, was mandatory, and the discovery and cultivation of an able minority—not so small a minority, but nevertheless a minority—became explicitly a problem for the statutory system of education, for the schools and after them, the universities. But our execution has too often been Laodicean, and our actual provision for the gifted has had a Fabian, if not an under-the-counter ineffectiveness that betrays the cramps of the class-structure, and our subm ission to egalitarian shibboleths in areas of our educ tional organisation where they have no place.

The broad problem [Harding has said] is that of a social group's use of its human wealth; whether as average people, who largely control the affairs of our group, we can make the best of those who excel us. . . . In our culture most people's sentiments are organised in a way that makes it easier to lavish attention on the unfortunate than to help the gifted to make the most of themselves. Either effort requires great emotional discipline—the gifted and the wretched are both very trying—but our culture gives more encouragement towards helping the unfortunate.

Galton had been the first to recognise the fact of psychological variation, and to bring its significance home even to Darwin himself. It was several decades before a systematic investigation of its extent could be attempted. In 1905, however, under the aegis of the Anthropological Section of this Association, and with Galton himself as chairman, a committee was appointed to plan a comprehensive survey. William McDougall headed a sub-committee, of which J. C. Flugel and Cyril Burt were members, to consider the inclusion of psychological measurements. Their purpose was not, like Binet's about the same time, to detect the defective, but to arrive at objective methods by which 'a sociological survey of the nation's manpower' might be accomplished. This was feasible only because the development of Galton's devices for analysing and assessing psychological characteristics was sufficiently far advanced.

Simultaneously, 'in the faith that psychology and life are not prime to each other'—the phrase has a pleasantly pedantic ring to it—another young

post-graduate student, L. M. Terman, was preparing a thesis at Clark University on 'Genius and Stupidity: a study of some of the intellectual processes of seven bright and seven stupid boys'. Slight though it may have been, no doctoral dissertation was ever more directly predictive of a life-work of research. By 1922 Terman was ready to begin the still-continuing *Genetic Studies of Genius*. Since then, the careers of 1500 men and women, selected for the most part on the basis of two intelligence test scores around the age of eleven, have been followed up at intervals with varying degrees of thoroughness. These individuals were obtained by sifting a school population of more than a quarter of a million to discover virtually all the children with intelligence quotients of 140 or more, or the bulk of those in the top one-half per cent of the population.

In the time available, I can glance only at some of the most generally significant indicators from this monumental example of longitudinal research. At the outset these points stood out:

(i) Over 80 per cent of the cases came from professional and semi-professional homes.

(ii) Many of the parents and other relatives of the group had themselves achieved high distinction.

(iii) In most respects, so far as these could be assessed, these able children were superior physically, and in personality, character, and general interests to average children of corresponding age.

(iv) With a mean intelligence quotient of about 150, their tested school achievement was correspondingly high, higher by two or three grades than that of the class in which they were enrolled. 'Bright children', Terman had said in 1915, 'are almost always underpromoted. They are rarely given tasks which call forth their best ability, and as a result they run the risk of falling into lifelong habits of sub-maximum efficiency', and in the earliest years, one is tempted to add, is this most the case.

The latest follow-up of this gifted group—95 per cent of them were still available thirty-five years later—confirms the picture that has been drawn in repeated studies throughout the decades. With few exceptions these able children become the able adults, 'superior in nearly every aspect to the generality.' That superiority is greatest in intellectual ability, in scholastic accomplishment, and in vocational achievement, and the intellectual superiority is maintained even by those whose careers have not been outstanding. Whether we look at the men or the women, at the individuals who have won national or international recognition in one field or another, whether we consider those who have achieved honourable mention in American Men of Science or the Directory of American Scholars, or those who have taken degrees, especially honours or higher degrees, or the number—86 per cent of the total number of men—whose occupations are in the two highest classes, the same relationships hold. By means of intelligence tests, 'achievement for beyond the average can be detected early in life, though the tests do not tell us what personality factors or accidents of fortune will affect the fruition of intellectual ability'.

Very significant, however, to the educator and to society are those very factors that modify the picture, that lower the correlations from one survey to the next, that blemish the success story and introduce the note of *weltschmerz* into the anthem of optimism. Even in this group, all of them in the top one per cent of the population as a whole, although there are very few outright failures, there are obvious differences in degree of success. Defining success as the extent to which his subjects had made use of their intellectual ability, Terman in 1940 compared the relatively highly successful top quarter of the men (Group A) with the relatively less successful bottom quarter (Group C). He summarised the findings thus: 'The educational and occupational records of these two groups present a vivid contrast. Of the A's, nearly all entered college, and 90 per cent graduated. Of the C's, 70 per cent entered and only 50 per cent graduated.' Nearly half of the A's but only 4 per cent of the C's graduated with obvious distinction. Ninety-six per cent of the A's as against 28 per cent of the C's were in professional or semi-professional occupations. These were the facts of early adult life.

In childhood, hardly distinguishable on intellectual grounds, these two groups were about

equally successful in primary school. In high school they began to draw apart, 'but it was not until the college period that the slump of [the C] group assumed alarming proportions', to show a difference in degree of success that must necessarily be due chiefly to non-intellectual factors. Terman's comments here will perhaps suggest a measure of caution in our acceptance of Crowther's optimistic forecast. Some of these adverse factors are obviously highly personal to the individuals concerned. But even in this academically relatively open society, in this American community that we regard as competitive but relatively non-stratified, socio-economic factors intervene.

> For one thing [says Terman] the family background of the two groups differed markedly. Nearly twice as many A parents as C parents had graduated from college, and a similar difference was found between the siblings of A's and C's. Fathers of the A's were more often in the professional classes. The important point here is that the educational tradition was stronger in the families of the A group.

The argument is reinforced by the fact that Jews were three times as common amongst the A's as amongst the C's. 'The Jewish child is under heavy pressure to succeed, with the result that he accomplishes more per unit of intelligence than do children of any other racial stock.' But in terms also of emotional stability and adjustment, and in personality traits, 'the C group differed clearly on the basis of parents' and teachers' judgment from the A's'. Fifteen years ahead of time, these teachers and parents had been able to discern personality differences that would later tell, and tell adversely, in adult achievement. In this gifted group

> success is associated with emotional stability rather than instability, with absence rather than presence of disturbing conflicts, with happiness of temperament and with freedom from excessive frustration . . . [but] beyond a certain high level of intellectual ability success is largely determined by non-intellectual factors, and . . . the number of persons who are endowed with abilities equal to great achievement is immensely greater than the number who will attain eminence.

In his own way, as we have seen, though harping over-much upon heredity, Galton had made much the same point. Genius, high and meritorious performance, was a resultant—the outcome of high ability allied with great energy and drive, directed especially, he would have said, along a particular line. A fair general level will attain no honours.

Now, of course, and as the time and place demand, there should be a moral to my tale. But it is hard to put it in a sentence, or even succinctly, except in the direct and simple terms of the hoardings that used to carry the disconcerting slogan of a particular firm of brewers in South Wales: 'It's BRAINS you want!' Today, for all I know, the hoardings may have gone, but the slogan has achieved academic respectability, and we are compassed about with a great cloud of planners (some of whom share a hide-out in the Athenæum), and Cassandras (whose prophecies, you will remember, were never to be believed) and prophets (Crowther I, the Prometheus Bound of the Advisory Council, and Crowther II, the Prometheus Unbound set free apparently at the invitation of the London School of Economics). Listening to them, you will have recognised the voice of the publicists of the new 'brain-power industry' which in Britain is gradually gathering headway towards its goal of 170,000 university places by 1970, or maybe 200,000 by the 1970's. The figure hardly matters. In any event, and in the interim, the problems of eighteen-plus give promise of being much worse than those alleged at eleven. Indeed, perhaps the time has already come when

> Bliss was it in that dawn to be eleven plus,
> But to be eighteen plus was merry hell.

Need we be surprised if some of the academic rabbits scuttle in alarm to their ivory burrows to speculate sourly upon the problems of overcrowding and under-staffing?

The situation is paradoxical. On the one hand, the Government, the advisors, and the official augurs, are apparently agreed that we must have more graduates, and that we must have them quickly—within the next decade. On the other hand, we are to have a grant-aided multitude who will want to be graduates, but who will not be able to find places, or who cannot find them where they want them. Somewhere on the sidelines there is an audible and disaffected but not disinterested group of spectators with Mr. Kingsley Amis as their cheer-leader, chanting 'more will be worse'.

Let us then face it, with Galton and Terman and many others in mind, but remembering also that we are now concerned with a much wider range of

ability than either of them considered. Ought there to be many more young people who continue their education to university level? On the face of it, the historical inevitability of it seems to be inescapable. Broaden the base of the educational pyramid as we did in 1870 and again in 1944, and immediately for some the upper slopes for the first time become visible and desirable. The democratisation of education means that more will be qualified to continue the ascent, and more will want to do so. The more certainly will this be true if rainbow lights play upon the summit, and if it appears that society's crock of gold—not to mention prestige and security—may be found there. If we extend the preparatory stages of education, as we have done, we cannot grumble if more would take advantage of what we have, not too clear-sighted!y, engineered. This cannot be gainsaid, and *they* cannot be denied.

At the present time, the demand is aggravated—and in the countries of the West our thinking is often conflicted—by the argument that the growth and the very security of society itself depend upon our response to it. Quantitatively, at least, some other people—most notably the Americans and the Russians—are doing better than we are in Great Britain. Again it seems hard to deny this. That *more* people are being educated for a longer time than in Great Britain is certainly correct. It is equally obvious that it cannot fail to have a bearing upon our way of life in a world where, the cold war apart, the race is to the trained intelligence. Of course America is not without its discontent about its comprehensive educational insurance policy in so far as it has depressed, by lack of stimulation, some of the ablest members of the community. This is the price that America has paid for being unselective. Years ago Galton suggested that 'if the hindrances to the rise of genius were removed from English society as completely as they have been from that of America, we should not become materially richer in highly eminent men'. In the light of Terman, you will be rightly disposed to doubt this conclusion. But the point still stands: removal of the road blocks is not enough. On the other hand, even Russian education, I gather, is not at the highest levels unselective. *Pace* Mr. Raymond Williams, it seems—even if we were prepared to accept a dictated consensus over a large area of our thinking—that we can hardly avoid some division into two cultures, a minority culture, and a majority culture.

Psychologically speaking, then, can the thing be done? As university provision is expanded, can we find enough young people who will be capable of education up to university level? Or is Mr. Amis right in asserting that 'more will be worse'? We know that educational achievement is related to ability, and we know a good deal about the way in which ability is distributed in the population as a whole. On this ground alone, there is probably little cause for apprehension. We could perhaps improve our selection procedures somewhat, and it is right that research should be directed to that end. But (1) even if we were to set our selection ratios for the universities impossibly high, as Terman and others have shown, not everyone will succeed; non-intellectual factors keep breaking in; (2) in education, if we are to arrange that all the good academic risks are to have an opportunity, inevitably we shall accept some poor ones; for their sakes we should like to keep the latter number low; and (3) is it not possible that *some* of our poor risks, our failures, in the past, would have turned out better if we in the grammar schools, and in the universities, had done a better job with them after they reached us? I shall return to this last point; it appears to me to be central to this whole problem of university expansion.

It is worthwhile, however to examine a little more closely the notion of the 'pool of ability', the intellectual capital upon which we have to draw. We can make heavy weather of this matter of intellectual resources, but perhaps for the present discussion a more simple-minded approach will serve. Crowther's basic figures are enough for my purpose. By the age of 16, nearly 80 per cent of the age-group had already finished with full-time education in England and Wales, and by 18 that figure had risen to approximately 92 per cent for boys and all but 95 per cent for girls. Virtually all those who might have even a chance of entering a university were going to be a selection from the remaining 8 per cent of the boys, and 5 per cent of the girls. The details of the picture can be filled in from the survey of National Service recruits (6500 Army; 2000 R.A.F.) made to the order of the Advisory Council. All of these men were tested on entry and placed in the appropriate ability (Summed Selection) group. Crowther's

tables show that in the Army's top selection group (P.R. 90 and upwards) most had stayed at school until they were 16, and the largest single sub-group remained to the age of 18–19. But in Selection Group II (i.e. the next 20 per cent of the population), two-thirds had left school at the minimum leaving age, and only 24 per cent had been candidates for G.C.E. But in that group, which is well short of the highest in terms of general ability, the number of G.C.E. passes achieved by those who tried was 3·7 on the average, as against 5·7 in Selection Group I. It seems reasonable to conclude, as Crowther does, that 'it is likely that there is much latent ability which for various reasons has not hitherto shown itself in educational achievement'. This conclusion is reinforced by the differential figures for girls, who fall off rapidly in the later years of school life and at the university stage because, it appears, they and their parents have been satisfied with a shorter school life and they, their parents, and their employers with lower academic qualifications.

Now it may well be that extending our sweep to retain larger numbers in school, and to send more into the universities and other forms of higher education is not going to increase very greatly the number of high fliers. If our assessments of potential are assessments of what S. J. F. Philpott used to call 'versatility' rather than of specific aptitude, not all of those who could take it will want a long-continued academic education. It may be, therefore, that the universities are already getting about as many of the intellectual élite as they can hope for. But short of this level, we may wonder whether we are utilising to the full the available stock of talent. Amongst the graduate teachers of mathematics and science at the present time, over 60 per cent have degrees below the level of second-class honours; this is a considerably heavier tail than in any other line in which graduates find their careers. Amongst all graduate teachers, not far short of 50 per cent are below the second-class level. It is obvious that even in an ideal world many of our brightest children would have to be taught for much of the time by people who are intellectually less able than themselves. But if this should happen too often or for too long, or if the teacher-pupil gap should become too wide the long term results might be serious. Not very much is known about this aspect of the pupil-teacher relationship. There is, however, no reason to be unduly fearful that the proportion of failures or of low quality degrees will necessarily increase greatly as our student population increases provided that we can expand the supply of good teachers for the grammar schools and universities. These are the important limiting factors. On the basis of the published figures for some universities, at least, there is no evidence of a dramatic deterioration in overall academic performance when the number of award holders was very considerably increased some years ago. Indeed, so far as my own university is concerned, the percentage of students graduating with honours in science actually increased under just such conditions.

There are other considerations that deserve examination if we are to be clear about our unrealised reserves of educable capacity. Certainly too many boys of good ability swell the ranks of the early leavers from the grammar schools. But the under-education of women and their under-utilisation in the professions and in industry have left the largest untapped reservoir of ability. This raises directly two major problems. First, it is easy to argue that the more people who are capable of benefiting from a university education who are also able to do so, the better for society, and for at least some of those people themselves. Myrdal and Klein comment, however:

> As long as the number of places is limited, and as long as the cost of this education is borne largely by the public, those who administer the funds will regard it as their duty to ensure that the money invested in education gives the maximum return. ... Women who have been admitted to universities on equal terms cannot escape comparison with men [in respect of their social contribution] and must not be surprised if the production of cultured and enlightened mothers—desirable as this may be—can only be regarded as a by-product, not as the main aim of university education.

The second, not unrelated, problem concerns what we allow women to do with their education when they have had it. Roughly 60 per cent of our teachers are women, less than 20 per cent of our doctors, less than 20 per cent of the administrative and executive grades of the local government service, and some 10 per cent of the administrative class of the Civil Service. In the United States 44 per cent of all the people employed in finance, insurance, and real estate are women; in Britain,

5 per cent. The sex ratios vary from country to country, but they differ on the basis of social mores and traditions rather than those of psychological sex differences. Mr. J. E. A. Stuart, Joint Assistant Head of Staff Department, I.C.I. Ltd., commented recently:

> I do not want to say much about this subject, except to confess that I.C.I. is traditionally a male stronghold and I think that in comparison the members of the Athenaeum can be regarded as militant progressives when it comes to associating with women. ... One cannot escape the fact that there are traditional difficulties to be overcome, but at the moment only 1 per cent of our Technical Officers are women. I would have thought that we could have gone as far as 2 or even 3 per cent without ruining the entire company! If one is talking about a marginal 5 per cent increase in technical effort, which is all we are looking for, then it is obvious that the employment of women could be a major contribution to the solution of our difficulties.

In some occupations that women have made their own—have, indeed, virtually created, like all forms of welfare work,—the professional woman has replaced the amateur, but infiltration of the masculine 'strongholds' is still very limited. Given continued full employment and present population trends, society will surely have to adjust its attitudes here, and find ways of coping with the administrative problems that the employment of married women throws up.

On the other hand, suppose that education can meet this new 'man-power', 'brain-power' demand that is being made upon it. Is there clear evidence that we in Britain at the moment know what to do with a greatly increased number of educated people if we had them? Throughout Europe, indeed throughout the world, the cry has gone out for scientists and technologists, but over several recent years I.C.I. has recruited only 60 per cent of the graduate scientists which their operating Divisions had asked for. Graduates in science and engineering draw salaries which overlap, even for the chemists, to a marked extent with those of the manual workers, and the salaries of the women science graduates are very similar to those of male manual workers in industry. There is, we are told, a seller's market for brains, but they do not seem to command a very high price, nor to be always very urgently sought after. Is this one reason for the slower expansion of our economy?

More important, perhaps, is what industry generally does with its ablest young people after it hires them. The percentage of first-class honours men among the graduates in industry is nearly three times as high as it is in teaching—higher, indeed, than anywhere else except the staffs of the universities and the Scientific Civil Service. We may not yet have travelled far down the facile slope to William H. Whyte's Organisation-Avernus, but are we perhaps on the brink? I am not an economist, but I am not convinced that even the economists or the politicians are clear about the criteria for the extrapolations that we are making or guessing at in respect of our need for manpower with this or that kind or degree of education and training. Some critics of industry within the universities, themselves concerned with the training of scientists for the electrical and chemical engineering fields, have certainly suggested that it is not the special scientific knowledge or skills of their graduates that are being utilised. If this is so —and it should be clear that I cannot myself say that it is so—it suggests that there are elements of conservatism and traditionalism in our social organisation that will block the advances to which a body of educated people might contribute. We can, of course, agree to make the maximum effort to develop our educational system. But we should be happier if the plan could be an intelligent one, based on intelligible reasons and at least *some* relatively specific predictions about the needs of society. We should be happier also if there were more evidence of fresh thinking and of the capacity and the desire for productive innovation.

At the end of it all, a psychologist's word about the universities themselves. From their point of view there are only two aspects of the problem on which I wish to comment. The suggestion, if I may borrow a phrase that Crowther uses in another connection, that they are traditionally concerned with 'the training of an intellectual aristocracy on whom the most stringent academic demands can be made' is only partially true, and it has overtones that will certainly be unpopular in some quarters. But it is necessary to reassert the point that was implied throughout the earlier part of this discussion, namely, that there *is* such a highly intelligent minority who will be the primary concern of the universities. But here we come to a stop. We do not know enough about the qualitative differences in high level mental functioning that

may be neglected or obscured in our quantitative assessments. For Galton, and for Terman also, however, high ability implied an element of creativeness that we at least must strive to foster. I am not now concerned with problems of specific aptitude, but rather with that element of creativity that Guilford and his colleagues have investigated in an interesting series of papers over the past ten years or so. There is here a line of research that ought to commend itself to the universities and to their psychological departments. It has not yet done so to any marked extent, and I have a strong suspicion that at least some of our university teaching techniques have been ill-designed to encourage or to stimulate this element of creative originality in their students.

The problem is the more acute now that the universities are already receiving considerable numbers of first generation immigrants from the grammar schools; this influx will continue to increase over the next few years. Now it is not, I have suggested, the *ability* of these people that we need be anxiously concerned about. It is rather, if I may use the term somewhat loosely, their 'attitudes'—Sir Cyril Burt might have called it their 'ideology'—their attitudes to knowledge, to learning and scholarship, and the disinterested quest for truth. These phrases have a platitudinous ring, but they are not yet fly-blown; and without a concern for these things even the able student will be unfitted for the university arena before the contest begins, or will be at least severely handicapped when he gets there. The universities must recognise that this is in part *their* problem, though it is reasonable that they should look to the schools for help. Whether we are to have Sir Geoffrey Crowther's kind of Sixth Form, or Mr. Peterson's, it is this sort of head of steam, this complex of motives, that their pupils should develop during their time there. The outcome, it is to be hoped, will be a kind of imaginative freedom, rather than conformity or a desire merely 'to satisfy the examiners', and it will demand freedom if it is to flower. But it will not flourish in the atmosphere of pedagogic *laissez-faire* which we have too long and mistakenly regarded as the hall-mark of the university trade. Intellectual eagerness is not the most obvious characteristic of the university entrant of the mid-century. In the immediate future, we must look to the schools to stimulate it, in the hope that the universities will have teachers of sufficient number and quality to respond to it, and these not only in their departments of science and technology, but also in the humanities and the traditional Arts subjects. 'Broad general degree courses' are proposed by some as the response to the challenge, and for some students they may be the right answer. But it is the teachers and the taught who matter, and I should pin my faith to people rather than to programmes. The immediate cause of our contemporary educational agitation has been the demand for 'more and better scientists, engineers, and technicians to produce the technology for an opulent peace and more lethal weapons of war'. Many have had no joy of this apparently one-sided cultural revolution, but in so far as it has stimulated in virtually every country, an active scepticism of the traditional educational instruments, institutions, and philosophy it has opened up enormous possibilities for good. A community that lives complacently upon the inheritance of accumulated experience that we call its tradition is already dead, however rich and splendid its past may have been. But we do well to remember that, without that past, and without a clear and just appreciation of its meaning for us, our future advance will be feeble, lacking in impetus, and uncertain and wavering in direction.

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BLACK SHALE, OIL AND SULPHIDE ORE*

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In a city where, at its first British Association meeting (1868), T. H. Huxley explained the origin of chalk, and R. A. C. Godwin-Austen delivered his address on the western margin of the North Sea basin, the subject of black shale may seem an unpromising one. Yet it is an appropriate sequel to the observations of my predecessor in this chair at the 1935 Norwich meeting, H. G. A. Hickling, who discussed on that occasion the petrology and genesis of coal. One of the merits of my subject is that it illustrates how a geologist's reasoning proceeds, as far as it can, along uniformitarian or actualistic lines, starting from what may be observed in process at present, and using this information to interpret past events.

Black shale is a commonplace lithology, represented in every geological system from early Pre-Cambrian to Recent, though in the more ancient rocks it has generally been metamorphosed to graphitic schist and in the youngest deposits its condition may be that of clay rather than shale. There is strong reason to suppose that living matter is indispensable to its formation, for it can be shown that the black pigment is of organic origin, made up of the principal biophile elements carbon, hydrogen, oxygen, nitrogen. Only in the metamorphosed rocks have the volatile elements been eliminated, leaving free carbon. The problems that I propose to discuss are, firstly, the conditions necessary for the preservation of organic matter in argillaceous sediment; secondly, the geological aspects of the partial conversion of the organic matter into hydrocarbons of petroleum type; and thirdly the concentration of certain metals as sulphides in the black shales.

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Black Mud

In the presence of oxygen, the highly-organised molecules that make up living matter are quickly destroyed upon the death of the organism, whether it be plant or animal. This is true when the dead tissues are exposed to the atmosphere, but it is also true that in the sea as well as in many bodies of fresh water, there is sufficient oxygen even at considerable depths to enable the organic material to be converted into carbonates, phosphates, nitrates and water. This is particularly the case where strong bottom currents flow, or where, in the lakes, a seasonal overturn of the water takes place. Thus sediment types characteristic of littoral or current-stirred off-shore seas seldom contain much organic material. Black siltstones are less common than black shales; black sandstones very rare and conglomerates with an appreciable organic carbon content in their matrices almost unknown. Limestones, like the Lower *Dibunophyllum* zone limestones of the Carboniferous, or the Chalk, are often white or nearly white; though some limestones exhibit dark carbonaceous pigmentation; these, however, are beyond our present scope. The chief repository of the organic material which escapes total destruction, apart from coal seams where it is highly concentrated, is black shale, the compressed and indurated rock formed by diagenesis from black mud. Our enquiry must start, therefore, from those places where black muds and clays are accumulating now.

It must be noted, however, that not all black muds will produce black shale. In some, the black colour is largely due to newly-precipitated iron sulphide, supposed to be in the form of hydrotroilite (generally considered to be $FeS.nH_2O$, but $FeS.H_2S$ according to Volkov[1]). This crystallises to form pyrite or marcasite, the change being

accompanied by a lightening of the colour to grey or pale grey. Nevertheless, it is doubtful whether the ideal situation where the only pigment in mud is hydrotroilite is ever achieved, for as described below, the formation of sulphide is intimately related to the presence of organic matter. Other possible black pigments may be dismissed as unimportant in muds; manganese compounds seldom become sufficiently concentrated and the minerals magnetite and ilmenite which, when abundant, produce black sands, are as far as I know unknown in micron-size aggregations sufficient to affect the colour of clay.

The environments in which black muds are forming at the present time may be summarised as follows:

(*a*) *Ill-drained terrestrial swamps;* the *peat-bogs* of high latitudes, like those of Dartmoor and the Pennines; and the *piedmont swamps* of lower latitudes, like those of the South-eastern United States. The normal product of the incomplete decay of terrestrial vegetation under these conditions is peat, the first stage of the series leading to coal; but peat and peaty soil may eventually be eroded and carried away by rivers to contribute major quantities of organic material to deposits forming in other environments. The peat-bog environment is characteristically highly acid, and iron tends to be taken into solution. Sulphur is not of great importance in the plants concerned and for both these reasons, iron sulphide formation is limited in scale in the early stages of coal-series reactions.

(*b*) *Eutrophic* (*highly nutrient*) *lakes*, where the production of living matter is at such a high rate that insufficient oxygen is available to oxidise the dead organisms before their tissues are buried in the sediment forming on the lake floor. J. L. Hough[2] remarks that the extent of the oxygen-deficiency in the bottom waters of a temperate-zone lake is a fairly accurate measure of the productivity of the lake. Reducing conditions generally exist here, at least during the periods of stable stratification. These conditions may not apply when isothermal conditions permit overturn, in spring and autumn in the case of temperate-zone lakes, once a year only in the case of subtropical lakes. Hough suggests that banded sediments are likely to result, where oxidised and reduced layers alternate, if overturn regularly recurs.

In many such lakes floating plants (phytoplankton), and green algae, are the most abundant living organisms, providing, directly or indirectly, the bulk of the organic material incorporated in the lake sediments. Here the environment tends to be neutral, the water colourless as compared with the brown water of the peat-bog. Sufficient sulphur is available to make iron sulphide formation possible. E. Gorham's[3] recent study of the carbon/sulphur ratios in sediments from the English lakes showed that these are lower in reducing than in oxidising muds, and much lower in fertile than infertile lakes; thus fertility leads to reducing conditions on the bottom and favours the precipitation of sulphur as sulphide. In an investigation of sediments from Danish lakes, K. Hansen[4] finds that where the organic material in the bottom sediment is acid, the content of organic carbon exceeds 50 per cent, and the carbon/nitrogen ratio exceeds 10. The conditions here resemble those of environment (*a*) of the present classification. On the other hand, where the organic material is neutral, the organic carbon content is less than 50 per cent, the C/N ratio less than 10; this is the situation typical of a colourless-water lake.

(*c*) *River estuaries, tidal lagoons and the tops of deltas.* The foetid black muds revealed at low tide in the estuaries of rivers in temperate countries are a matter of common observation. They might be thought at first sight to contradict that statement already made that moving currents create conditions inimical to the preservation of organic matter; but it must be remembered that in estuaries the interaction of tide and river current, fresh and saline water, provide a relative check in water velocity and hence lead to an increased rate of sedimentation. Moreover, K. O. Emery and R. E. Stevenson[5] show that in a 'normal' estuary, where fresh water flows out above salt water, there is only very slow replacement of bottom water by subsurface water from the open sea, and the bottom water becomes deficient in oxygen, thus enabling black mud to continue to accumulate. In lagoons and in depressions on the tops of deltas, stagnant bottom-water conditions may also be created by the existence of sand bars, preventing free circulation. The actual rate of sedimentation in estuaries and lagoons, which provide quiet settling-ponds for the rivers on their way to the sea, is likely to be many times greater than in the sea itself. The

important factors in the preservation of organic matter in the bottom muds are, therefore, its high rate of accumulation and the oxygen-poor bottom waters.

The fauna of the estuarine-lagoonal environment consists, in decreasing order of importance, of marine forms able to adapt themselves to the variable conditions of salinity; of brackish-water forms, and of a minority of freshwater creatures. The hard parts of organisms stand a good chance of being preserved after death, and the soft parts contribute to the black mud. According to J. W. Hedgpeth[6] bottom conditions are not such as to inhibit life, and burrowing organisms may flourish.

Excellent examples of the estuarine-lagoonal environment are provided by the Waddens, enclosed behind a fringe of islands extending along the Netherlands and Danish coasts northward from Texel, at the entrance to the former Zuider Zee.

entrances. Here there are two well-investigated cases; the Black Sea, described by Russian workers including Androussow, Arkhangel'sky and Strakhov whose studies have recently been summarised by H. Caspers[8]; and the Norwegian fjords, with which the name of K. M. Strøm[9] will always be associated. The Black Sea, with a maximum depth of 2243 m., has an average depth of 1197 m. and is connected to the Mediterranean by the shallow Bosphorus (Fig. 1). Considerable quantities of fresh water are supplied by rivers entering mainly from the north; the Bosphorus bottom current brings in salt water with 38 per mille salinity. The upper waters of the sea are thus brackish, with salinity 18 per mille maximum. Below the shallow surface zone, the bottom waters are trapped and stagnant as a result of the high sill separating this basin from the open sea, and the lack of a vertical circulation, the colder, heavier water always being

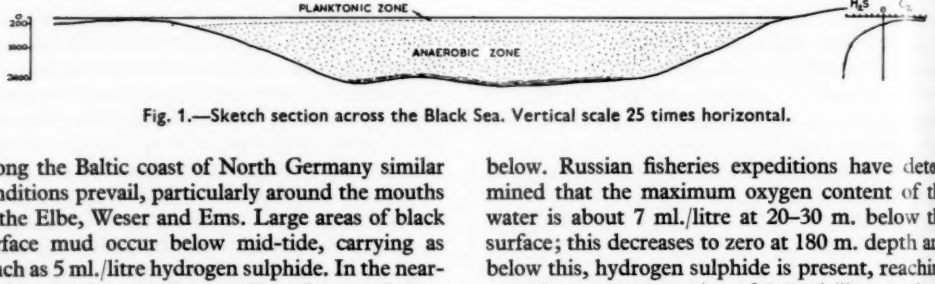

Fig. 1.—Sketch section across the Black Sea. Vertical scale 25 times horizontal.

Along the Baltic coast of North Germany similar conditions prevail, particularly around the mouths of the Elbe, Weser and Ems. Large areas of black surface mud occur below mid-tide, carrying as much as 5 ml./litre hydrogen sulphide. In the near-surface mud, according to Van Straaten,[7] iron monosulphide is forming, but beneath this there is a zone where this is changing to pyrite. Although areas of up to 1600 sq. km. of black mud have been reported from the Bay of Danzig, this is a maximum figure, and black mud is by no means the only type of sediment forming in this environment. There are substantial areas where the mud is not black; there are banks of lamellibranchs; there are sandy beaches and bars. On the regional scale, a considerable variability of deposits is to be expected. In detail, the black muds may show poor sorting, cross bedding, lamination, slump structures and mud cracks, all reflecting the conditions under which they were formed.

(*d*) *Deep land-locked sea-basins or arms of the sea, separated from the open sea by silled straits or*

below. Russian fisheries expeditions have determined that the maximum oxygen content of the water is about 7 ml./litre at 20–30 m. below the surface; this decreases to zero at 180 m. depth and below this, hydrogen sulphide is present, reaching a maximum concentration of 6·2 ml./litre at about 1500 m. Normal life is virtually confined to a surface layer of little more than 50 m. depth; below 180 m., only anaerobic bacteria can exist. In the surface zone, the biomass has been estimated (in millions of tons) as: Phytoplankton (rich in diatoms), 0·36; Phytobenthos (chiefly algae), 2·40; Bacteria, 2·70. A large part of the organic material produced sinks down into the anaerobic zone. The carbon content of the bottom ooze has been variously estimated at from 20 to 35 per cent, but Caspers quotes the figures for the recent ooze as 1·74 to 4·54 per cent. Pyrite is actively forming, but the sediment, when dried, is grey rather than black. The rate of sedimentation over the whole basin has been determined to be 0·5 mm./year. Black mud underlying the bottom ooze, to which

the higher carbon figures quoted above presumably refer, is considered to belong to an older geological period; but probably it formed under comparable conditions.

The Norwegian fjords are glacially-overdeepened valleys inundated by the sea. Many of the 32 studied by Strøm, proved to be basins with shallow thresholds, the sills separating them from the open sea having been produced either by excavation of the basin by ice, or damming up, or a combination of both processes. Stagnation of varying degree was proved to exist, the water below the near-surface zone being poisoned with hydrogen sulphide. The highest recorded concentration of H_2S was 40 ml./litre. An increase of H_2S contents of bottom waters was observed in two cases as 1·0 and 1·5 ml./litre per annum. With increasing stagnation, a rise in temperature was found to be produced which eventually caused the stagnant waters to become less dense than the cold water entering over the threshold and in this way renewal of the bottom waters is enabled to take place. The lifting of the poisoned waters to the surface may cause catastrophic death of the fauna normally inhabiting the surface zone. The bottom deposits are black organic muds with up to 23·4 per cent carbon; the rate of sedimentation is stated to be very uneven. Irregular laminations were observed in the sediments of two fjords, and in one, the Drammensfjord, regular varves were found in bottom mud formed under anaerobic conditions, resting upon clay of normal type.

A noteworthy feature of this type of environment is that, since the poisoned bottom waters exclude benthic organisms from all but very shallow depths on the sides of the basin or fjord, the hard parts of organisms buried in the bottom mud may be expected to be derived from swimming or floating plankton almost exclusively.

(*e*) *Basins in the sea bottom.* It may be anticipated that conditions similar to those described for the Black Sea and the fjords also exist where deep depressions in the sea floor are receiving sediment. W. H. Twenhofel[10] states that black muds accumulate 'in deep holes on neritic bottoms' and notes that they do not form on elevated or level parts of the bottom of the open sea. G. M. Lees[11] found black mud, almost unpopulated with life, over extensive areas of the Arabian Sea but it is not certain that this occupies a closed depression. Recently a very detailed investigation of the basins in the sea floor off southern California has been undertaken by K. O. Emery and S. C. Rittenberg.[12] Altogether thirteen such basins lie off the coast between Los Angeles and San Diego, with their long axes generally parallel to the coast. The largest is 110 km. long by 28 km. wide. The maximum depth reached in any basin is 2100 m., but differences in elevation between sill and bottom may amount to as much as 975 m. The basins are comparable in size with the two oil-producing basins (Ventura and Los Angeles) now being exploited in the area. The deeper waters of the open sea are excluded from the basins, which are at sill temperature throughout and isohaline. The sediments are mainly clays of grain-size 4 microns and less, but coarser layers containing foraminiferal tests occur. The colour of the sediments is green, not black, and it is evident that the degree of stagnation is not as high as in the Black Sea and the fjords. This is shown by the fact that the redox potential *Eh* is usually positive at the sediment surface, though it quickly changes to negative within the sediment, and hydrogen sulphide appears. Pyrite is forming by replacement or coating of radiolaria, foraminifera and diatoms, but the quantity is small. Organic matter which is being buried with the sediments, has its source in the phytoplankton occupying the top 150 ft. of the sea. The authors calculate that only one-sixteenth of the organic matter escapes destruction, but even so, enough is preserved to be an important source of future oil. Although black sediment is not found in these basins, the observations on them are of considerable interest.

The brief summary of the various situations in which black muds are forming today shows that W. H. Twenhofel's[13] contention that black shales can form under a wide variety of conditions, is fully justified. Two main conditions are, however, involved, at least one of which must be fulfilled if organic matter is to be preserved from destruction, and contemporaneous (syngenetic) sulphide produced in quantity; either there must be restriction or exclusion of oxygen-bearing water; or sedimentation must proceed so rapidly that the organic matter is buried before it can be eliminated. Obviously both conditions may operate in some cases; but we may suspect that not all black shales were formed in a 'restricted' environment; and

certainly by no means all were formed in a 'euxinic' environment, if that term is to be taken to mean conditions strictly comparable with those in the Black Sea.

Bacterial Decomposition

Emphasis so far has been placed upon the preservation of organic material, but it must not be supposed that it is preserved without substantial chemical change. The means by which the change is accomplished are biochemical rather than chemical, the results of the activity of the teeming microflora in the waters through which the decomposing remains sink, as well as in the black muds themselves. Bacteria, simple unicellular organisms whose maximum size rarely exceeds a few microns, are the active agents in the process. Their ecological tolerance is greater than that of any other form of life; they convert land plants into peat; they occur in lakes, seas and have been found at depths exceeding 5000 m. in the oceans. In sediments, although they decrease in numbers below the shallow layers, they persist to considerable depths and they have been found in deep oilfield brines. For the present purpose, the usual distinction into aerobic and anaerobic groups is useful; the former are active so long as adequate oxygen is available, and their ultimate effect is to convert carbon into CO_2 or carbonate; hydrogen into water; nitrogen into NH_3 or nitrate. A large number of different transformations may be effected, a consideration of which is outside our present scope; but it may be noted that Zobell[14] points out that some bacteria can convert waste and dissolved organic matter into bacterial protoplasm, consisting of various proteins, fats, oils and other cell substances. This in its turn provides food for bottom-dwelling creatures in the sea. The aerobic bacteria are not only the chief agents of decomposition of organic matter, but play a constructive part as well.

Below the limit of available oxygen, which may as we have seen lie within the lake or sea (as in the case of the Black Sea), at the water/sediment interface, or within the sediment itself, anaerobic bacteria take the place of the oxidising type. These consume oxygen, and include the important group of the sulphate-reducing bacteria, which bring about the change from sulphate to sulphide. In a recent review of the dissimilatory sulphate-reducing bacteria, that is, those whose major energy-yielding reactions are linked to a reduction of the sulphate to the sulphide ion, Postgate[15] adopts the view that only very few species possess this property. These are regarded as variants of the freshwater species now called *Desulfovibrio desulfuricans*, and both marine and freshwater types are known. The sulphide may appear as hydrogen sulphide, or may combine with certain metals; the presence of a small amount of iron is apparently necessary to the existence of the bacterium. The sulphate may originate from the activity of true sulphur bacteria, which decompose the amino-acids of protoplasm; or it may be the sulphate normally present in sea water. Within the anaerobic zone, decomposition of the organic protoplasm continues—for example, *D. desulfuricans* is able to bring about terminal metabolism of simple 3- and 4-carbon compounds in a marine environment—but the process is slower and less complete than in the aerobic zone, and in effect there is a relative conservation of organic compounds in the anaerobic zone; hence black mud.

It has been stated that almost the whole of the hydrogen sulphide in the Black Sea is produced by the activity of *Desulfovibrio*. Caspers[8] cites the following reactions:

$$R''SO_4 + 2C = R''S + 2CO_2$$
$$R''S + CO_2 + H_2O = R''CO_3 + H_2S$$

from which it will be seen that if R″ is Ca, as it is likely to be in sea water, calcium carbonate is also produced in the process. Thus in the Black Sea, there is a progressive increase in carbonates and decrease in sulphates with depth.

Humus and Sapropel

H. Potonie[16] recognised as long ago as 1908 that a useful distinction can be drawn between the products of the decomposition of land plants and associated organisms under strongly acid conditions, and those resulting from decay of aquatic plants and the organisms associated with them in neutral or nearly neutral water. For the unconsolidated product of the first process I shall use the term *humus*, this usage being consistent with that of Waksman[17] though not with that of authors who refer to marine humus. Humus is a dark brown to black substance, insoluble in water, representing a natural organic system in dynamic equilibrium. As understood here, it is a terrestrial accumulation,

reaching its maximum development in swamp conditions; but as already noted, it is often eroded and transported to lakes or to the sea. The essential constituents are cellulose, hemicelluloses and the more resistant lignins and proteins.

For the unconsolidated product of the decomposition of aquatic plants and associated organisms under neutral or mildly alkaline conditions, the term *sapropel*, though not entirely satisfactory, appears to be the best to use. This is the organic sludge which accumulates, where conditions are favourable, on the bottom of lakes and of the sea. The algae, which are the main source of this material in many aquatic environments, differ significantly in composition from land plants in that they are rich in proteins and poor in carbohydrates, whereas the reverse is the case with land plants. Thus sapropel normally contains more nitrogen than humus; indeed there seems to be general agreement that humus may be recognised by a carbon/nitrogen ratio greater than 10, whereas sapropel usually shows C/N less than 10. It is interesting to compare the figures obtained by Tj. Van Andel and H. Postma[20] in their study of recent sediments in the Gulf of Paria, where C/N values exceed 10 near the Orinoco delta, and remains of cellulose and lignin are present; while farther out in the Gulf, the ratio drops below 10 and there is no evidence that terrestrial plants have contributed to the organic content.

It will be noticed that in this discussion of the decomposition of organic matter, no mention is made of the soft parts of animals. The reason is that, broadly speaking, the contribution from this source is not quantitatively significant. The total carbon content of plants has been estimated by Kalle[19] to be 75 times greater than that of animals; other authors give the figure as 60, but there is little doubt that it is of the right order of magnitude. Further, animals ultimately derive their food from plants, the photosynthetic activity of chlorophyll-bearing green plants being fundamental in that it is autotrophic; that is to say, it converts inorganic into organic substances. The relative importance of the marine and terrestrial habitats is indicated by Rabinowitch's figures[20] for the yearly total fixation of carbon on the earth; he considers the probable value for marine plants to be $15 \cdot 5 \times 10^{10}$ tons compared with $1 \cdot 9 \times 10^{10}$ for terrestrial plants. It is, however, unlikely that the relative rates of fixation have remained constant in earlier geological periods.

Organic matter can thus be observed in process of accumulation, probably largely in the colloid state, on land as humus, and in lakes and seas as sapropel. Sediment from the land may contribute humus to lake and near-shore marine deposits, so that a large area of mixed origin must be recognised. The further fate of the organic compounds will be considered after some examples of consolidated black shales have been cited.

Black Shale

Some well-known examples of black shale in ancient formations may be considered in terms of the environments in which black mud is now accumulating. Black shales are sufficiently frequent in the geological column to make it out of the question to attempt any comprehensive discussion, but it is hoped that the examples given below cover most of the familiar types. They will be considered in order of increasing age:

(*a*) The Lower Cretaceous Wealden Series of south-eastern England has been the subject of a detailed environmental study by P. Allen[21] who concludes that the rhythmic sediments record three advances of a delta into a freshwater lake. Comparison is made with modern deltas which Allen has also investigated. The dark pyritic Wadhurst, Grinstead and Weald clays are considered to have been formed either in levees or back-swamp ponds on the delta top, or else during the advance of the Wealden Lake over the delta, the latter interpretation being preferred. Soil beds in which *Equisites lyelli* grew may have contributed humus to the clays. It appears to be easier to envisage stagnation in terms of the back-swamp interpretation.

(*b*) The English Jurassic not only contains humic shales, rich in well-preserved plant remains, in the Deltaic or Estuarine Series, but also dark marine sapropelic shales. Notable examples are the black Jet Rock Shale and the Alum Shale of Yorkshire (compositions, Fig. 2). The fauna includes cephalopods and other free-swimming creatures, but the abundant remains of lamellibranchs, gastropods and worm tracks show that bottom life was far from impossible. Pyritisation of fossils is widespread; according to J. E. Hemingway[22] myriads of tiny spheres of this mineral occur in

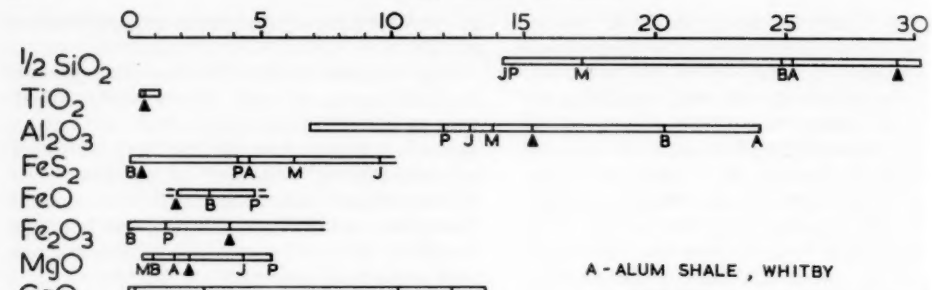

Fig. 2.—Main constituents in black shales, compared with average shale. Open lines indicate the range of each constituent in published analyses. Analysis B, black shale in Coal Measures cyclothem at Bersham Colliery (G. D. Nicholls and D. H. Loring (1960): *Clay Min. Bull.* **4**, 201); Analysis P, pot clay marine band, Millstone Grit (J. T. Greensmith (1958): *J. Sed. Pet.* **28**, 209); Analyses A, J, M, new full analyses by Pattinson and Stead (1961); specimen M from Elwick (A) borehole of National Coal Board, depth 546 ft. Scale gives percentages.

these shales. The ammonites not infrequently contain crude oil in their body chambers, and the Jet Rock Shale yields oil upon distillation.[23]

(*c*) The Permian 'Marl Slate', the equivalent in north-eastern England of the Kupferschiefer of Germany, is a black calcareous siltstone rich in bituminous constituents and in microcrystalline pyrite when unweathered. In places great quantities of palaeoniscid fish remains occur; plant remains are not infrequent but fossils from a bottom fauna are conspicuously absent. The deposit is thin (0·3 to 1·0 m.) and seems to represent a unique phase of sedimentation in the Zechstein lagoon, of short duration. Further reference will be made to this in connection with sulphide ores.

(*d*) The Carboniferous System contains great thicknesses of grey shale, with at least three distinct types of very dark shale. Black marine shales occur as thin beds in the Westphalian and as somewhat thicker beds in the Namurian. Goniatites are characteristic, but thin-walled brachiopods and lamellibranchs (e.g. *Pterinopecten*) also occur. The goniatites were free-swimming; the other fossils may have been drifted in. Foul bottom conditions, created by abundant putrifying humus, may well have prevailed during some of these marine episodes, but not of necessity during all of them. Oil is occasionally found in 'solid' goniatites; pyrite though generally present, is seldom abundant. The Bowland Shales of the West Yorkshire–Lancashire trough and their equivalents represent thicker deposits of essentially similar origin; dark lenticular limestones are associated with them. The black shales of Pennsylvanian age in Iowa and Nebraska in which the organic carbon content varies up to 23 per cent, have been held by C. E. Peyton and L. A. Thomas,[24] to have formed under conditions comparable with the Dutch Waddens. The mussel bands of the British Coal Measures may well represent conditions something like this, but the marine bands are to be taken as representing rapid mud accumulation in a trangressive shallow sea.

The unfossiliferous shales and mudstones of the Coal Measures and the Yoredales, representing swamp, lagoonal and, at times, delta-top deposits cut off from the sea, may be regarded as owing their carbonaceous content largely to humus from the soils of the coal-forming forests. Chalybite

nodules are common and some iron sulphide is usually present, but these minerals may indicate strongly reducing conditions during diagenesis rather than in the waters in which the mud accumulated. In a recent study of the chemistry of a Coal Measures cyclothem, G. D. Nicholls[25] has suggested that sulphide-enrichment in the lower part of the succession corresponds with stronger reducing conditions during deposition, while chalybite enrichment in the upper part was controlled by milder reduction, but he stresses that the conditions refer to the upper part of the sediments and not necessarily to the overlying waters.

Oil shales, torbanite and cannel represent a specialised facies within the Carboniferous in Britain, and are found elsewhere in other systems. Sapropel from algae, has been shown to be a major constituent of these rocks, which yield petroleum on distillation. Humic constituents are normally present also. Macgregor[26] has concluded that the Scottish oil shales were laid down in an irregular inland depression in which alternating lagoonal and estuarine conditions prevailed; an abundant freshwater fauna flourished, but at certain times there was short-lived accesss of the sea to the lagoon, forming marine bands.

(*e*) Black shale is widespread in the Devonian System in Europe and North America. The Marcellus–Ohio–New Albany–Chattanooga bituminous shales of the north-eastern United States, characterised by thin, even bedding and thus accumulated below wave base, have been interpreted by J. L. Rich[27] as having formed very slowly in water not less than 200 m. deep under quiet toxic conditions. The large area covered by these shales, not less than 850,000 sq. km., shows that at times in the past, conditions favouring this lithology prevailed over far larger areas than they are known to affect today. The fauna includes conodonts, pteropods, orbiculoid and linguloid brachiopods and crinoids. All but the last two groups were planktonic; the thin-walled brachiopods could have been transported on floating logs or seaweed. Thus widespread foul-bottom conditions seem to have existed at this time, and perhaps here a true euxinic environment was approached. Rich maintains that these shales were deposited in the deeper, unaerated parts of an extensive marine basin into which sediment was coming only slowly.

(*f*) The final example to be mentioned is that of the graptolitic facies of the Lower Palaeozoic geosyncline on both sides of the Atlantic. The graptolites are normally preserved as carbon markings in the shale, with some chitin remaining in certain instances; or they may be preserved in relief in pyrite. Marr,[28] considering the conditions under which the Stockdale Shales were formed, postulated open bays rather than closed basins like the Black Sea. The fauna typical of the graptolitic facies is a floating one; Ruedemann[29] pointed out the significant absence of worm tracks or borings and while admitting the necessity for near-surface currents to drift the organisms, thought that vertical circulation in the geosyncline was weak or absent. To what extent this conception can be harmonised with the presence of graded bedding, now generally interpreted as due to turbidity currents is a question worthy of brief notice; though it might be maintained that rocks like the Bannisdale Slates of the Lake District, which show this feature particularly well, contain only very rare graptolites. There is perhaps a case for the alternation of periods of quiescent stagnation with periods of rolling turbid flowage; or alternatively, perhaps the turbidity currents fail to promote vertical circulation.

Carbon Compounds and Petroleum

We may now consider further the fate of the organic matter deposited when black shale is forming. As already noted, it is subjected to chemical changes during its passage through the waters of the lake or sea, oxidation at shallow depth giving place to reduction either in stagnant bottom waters, or in the newly-forming sediment. Slow changes in the carbon compounds may be expected to continue during diagenesis and burial. Of the exact nature of these, we are at present only dimly aware. Starting from humic constituents, slow progressive elimination of oxygen and hydrogen gives rise to the 'coal series'. Several different lines of approach show, according to D. W. Van Krevelen and J. Schuyer[30] that what is happening is the development of large, flat molecules whose molecular weight may average as much as 2500, with increase in aromatic compounds accompanying increase in rank of coal. There can be little doubt that changes of a similar kind occur in black shale; for example, kerogen separated from

the Pierre Shale of South Dakota was similar in structure and composition to lignite or sub-bituminous coal.[31] The carbon–nitrogen ratio in the derivatives of humus remains high and tends to rise with coalification. In wood fibre it is of the order of 50; in peats it is lower but not less than 25; in brown coal it exceeds 80, in bituminous coal it is over 100. Nitrogen is slowly eliminated with the oxygen. At present I know of no certain evidence that liquid hydrocarbon is generated in this process, but some hydrogenation to form methane may accompany humic deposits. Nevertheless, the well-known lack of correlation between coalfields and oilfields—except in Pennsylvania—suggests that liquid hydrocarbons, with their small, light molecules, are seldom if ever of purely humic origin.

The sapropelic deposits have been considered to yield three main organic derivatives: (1) kerogen, the stable residue, insoluble in ether; (2) asphalt, similar to the ashphaltic portion of petroleum, and (3) hydrocarbons similar to those in the heavier fractions of crude oils. The kerogen, which greatly predominates over the other derivatives, shows carbon–nitrogen ratios a little greater than 10, but in normal sediments these appear, from figures given by K. O. Emery and S. C. Rittenberg,[12] to be substantially lower than in humic compounds. For example, for the post-Miocene sediments (8000 ft. thick) in the Los Angeles basin, the range is from 13·2 to 14·2; while for other sediments, ranging back to the Palaeozoic, the highest average is 16·7. The C/N ratio thus appears to give some indication of the provenance of the organic matter.

Crude petroleum, on the other hand, has a very high C/N ratio, exceeding 200. The presence of liquid hydrocarbons in recent sediments has only recently been demonstrated; previously the failure to find these was taken as evidence that they were generated only after burial of the sapropel. Now, however, J. V. Smith[32] and others, using modern chromatographic methods, have shown that liquid hydrocarbons are present in various modern sediments from the coastal regions of the south-western U.S.A.; and S. Judson and R. C. Murray[33] have demonstrated that hydrocarbons showing C^{14} activity are forming in the black sludge of Lake Mendota, Wisconsin. Nevertheless, it has been pointed out[34] that the hydrocarbons widely found in recently deposited sediments are not those that constitute the bulk of petroleum; either further changes occur, or petroleum is mainly produced by processes other than normal decomposition of organic matter. Among processes which have been suggested to enable 'complex organic matter' (i.e. kerogen) to be changed into petroleum are included (*a*) the normal chemical response to pressure, temperature, time and catalytic activity; (*b*) bacterial activity advocated by Zobell and his associates[35] as the principal dynamic agent maintaining the highly reducing conditions which favour hydrogenation in modern sediments; (*c*) radio-activity, which may provide a local source of mild heat and also of catalytic activity; (*d*) heat generated by skin-fraction between the rock particles during consolidation.[36]

There can be little doubt that light hydrocarbons may be generated in sapropelic shales during their formation, and that these rocks may therefore function as source rocks for oil. To be effective, the hydrocarbons must be expelled before the shale becomes impermeable; the oil then migrates until it is trapped in a sealed permeable reservoir rock such as an oil sand. Some sapropelic shales, for example the Cornu Shale of Rumania, are accepted as source rocks; but in practice the evidence shows that in many, perhaps in most black shales, the carbon has been retained in the form of stable complexes, and no petroleum concentrations which might be related to them have been found. On the other hand, many oilfields occur where no black shale is present in the stratigraphic column, as Trask's extensive survey into possible source rocks in the major American oil-producing areas showed.[37] While, therefore, the black shale environments provide the optimum conditions for the preservation of biophile elements, it may well be the case that they do not provide the best conditions for the hydrogenation necessary to the genesis of petroleum. It might, indeed, be maintained that the rocks are black because the organic matter has been preserved in polymerised form and not expelled.

Chemical Composition

In Fig. 2 the composition of a variety of black shales are compared with average shale. Three of the analyses (Alum Shale, Jet Rock Shale, Mar Slate) are new. Clay minerals account for the relatively high alumina and combined water

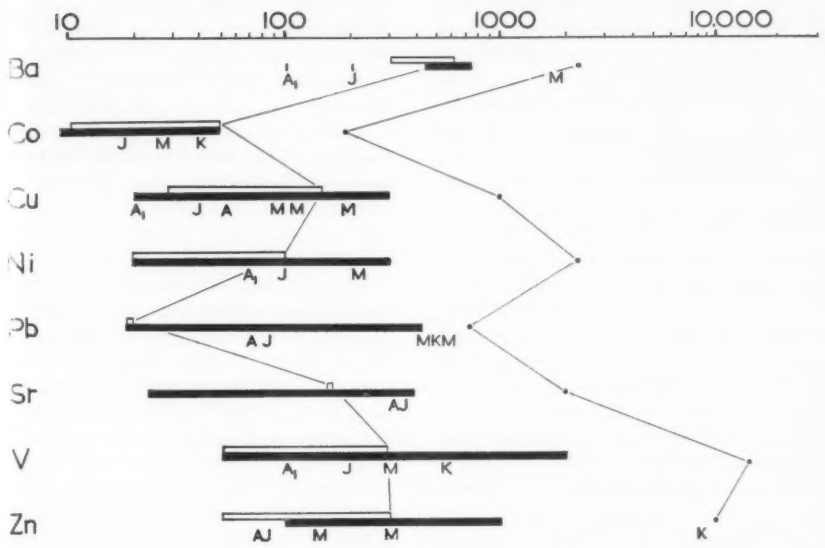

Fig. 3.—Minor metals in black shales, compared with ordinary shales. Open lines, ranges for ordinary shales; black lines, ranges for black shales; dots, maxima for black shales; data from K.B. Krauskopf.[38] A, alum shale; A_1, pyritic nodule in alum shale, Whitby foreshore S. of S. pier; J, jet rock shale, 1 mile N. of Robin Hood's Bay; M, marl slate (T. Deans[43] and new data for Elwick borehole); K, Kupferschiefer (V. M. Goldschmidt, *J. Chem. Soc.* 1937, 655). New determinations for A, J and M by C. H. Emeleus and D. M. Hirst. Scale, parts per million on logarithmic plot.

contents, and for part of the silica, but there is otherwise wide variation in major constituents, as is to be expected from the variety of sources and environments involved. In particular, the variation in carbonate content is noteworthy; there is no correlation between CO_3 and C such as might be expected in a broad way if all black shales formed under euxinic conditions.

The minor elements which are of special interest in connection with metalliferous ore deposits are considered in Fig. 3, which shows the ranges deduced by K. B. Krauskopf[38] for the contents of these elements in ordinary shales and in black shales. The crustal abundances of all the elements concerned lie close to or within the range indicated for shale. Black shale, when compared with average shale, shows an appreciable enrichment in As, Cu, Mo, Ni, Pb, V and Zn, and the maximum figures recorded in the literature for black shales other than those carrying metal ore-bodies, show figures very much above the average ranges. On the other hand, the new figures for the Jet Rock Shale and for the Alum Shale of Yorkshire and a pyritic concretion in it, serve as a reminder that enrichment in rare elements is not a necessary feature of black shales; the concentrations of the minor elements in these rocks, except Pb, being within the average for ordinary shale. The fact appears to be that if supplies of these elements are available, the black shale environments tend to favour their precipitation, adsorption or incorporation into organic complexes. This is well illustrated by the Marl Slate and Kupferschiefer.

Uranium offers a special case of the concentration of a rare element in black shale. Strøm[39] reported up to 600 p.p.m. U in the black muds now forming in the presence of hydrogen sulphide in the stagnant bottoms of Norwegian fjords. The greater radioactivity of shales compared with the sediments with which they are normally associated is well known and is used as an effective method of indirect well-logging. Some black shales, notably

those of the Upper Cambrian around Närke and Billingen in Sweden form important sources of the metal; these two districts yield 0·023 and 0·030 per cent uranium respectively. According to Swanson[40] some black shales contain 100 times as much uranium as other common sedimentary rocks. The combination of fine-grained sediment with reducing conditions evidently favours the retention of this metal, but according to Swanson's survey of over 5000 samples from American sources (more than half from the Upper Devonian Chattanooga Shale and its correlatives) it tends to be associated with humic rather than with sapropelic types. This raises an interesting question if applied to the Swedish occurrences, for no fossil land plants are known in strata as early as Upper Cambrian.

The capacity of black shale environments to bring about the concentration of minor constituents of the earth's crust raises three issues of current interest to economic geologists. Firstly, can concentration sufficient to produce workable metalliferous ore-bodies occur under favourable circumstances? Evidently this is possible where, as in the case of uranium, a low metal content is nevertheless valuable; but the wider question of base metal sulphide ore-bodies is more difficult and is to be considered below. Secondly, can waters eliminated from black shale during consolidation become effective mineralising agents in adjacent rocks? This subject has hardly been explored as yet, but it may offer possibilities; it is noteworthy that several speakers in the discussion of A. G. Darnley's recent paper on the Rhodesian Copper Belt ores,[41] which are in part concordant bodies in shale, suggested that these were emplaced very soon after sedimentation and most workers are agreed that they pre-date the metamorphism of the Katanga System. Thirdly, it has been proposed that sedimentation effects a partial concentration of minor elements, but that this is carried to the ore-forming stage after the sediments have been granitised. If this is so, the black shales might play an intermediate role. The possibility that local metamorphism might liberate metals from shale was investigated by H. L. Barnes[42] at Hanover, New Mexico, where the Devonian Percha Shale carries 70 p.p.m. Zn, 48 p.p.m. Cu; but he concluded that insufficient zinc had been extracted from the shale to account for the large tonnage of that metal in the ores of the district. He also concluded that lateral secretion from shale could not quantitatively explain the ore-bodies of the northern Mississippi Valley lead–zinc field, nor the vein deposits at San Francisco del Oro, Mexico. Although the results of this study were negative, there remains considerable scope for further work on shales as an intermediate source of metals.

Sulphide Ores

Frequent reference has been made to the formation of iron sulphide in black mud, and to its presence in black shale. The question now to be considered is whether partial or ore-grade concentrations of other useful metals as sulphides can be formed as part of the sedimentary processes producing these rocks. Some investigators see in sedimentary syngenesis a valid alternative to concentration by late-magmatic processes, applicable to some of the world's great ore deposits. There can be little doubt that if such a process can operate, the black shale environments would offer it the maximum chance of success, since here the reducing conditions indispensable to sulphide formation can be maintained not only during sedimentation, but also during consolidation and diagenesis.

The characteristics of a sulphide deposit formed *pari passu* with the accumulation of black shale would be that the ratio of its lateral dimensions to its thickness would be very high; that it would be independent of structural controls and that the sulphides would occur intimately mixed with the ordinary constituents of shale, but not with the gangue minerals which usually accompany hydrothermal replacements. A small number of major ore deposits do actually show these characteristics.

The Kupferschiefer, near the base of the Zechstein division of the Permian of Germany, which had already played an important role in very early geological thought as part of the Secondary Mountains of Lehmann and of the Flözkalkgebirge of Werner, was the first sulphide-bearing formation for which a sedimentary origin was advocated. It remains, in my view, the clearest case of the syngenetic style. The bed was worked for copper from early times in the syncline of Mansfield (now in East Germany) where, according to Deans[43] it averaged 22 cm. thick over 140 sq. km., and

yielded 16–20 kg./m² (2·9–3·6 per cent) of the metal. Copper ores also occur in two other areas of Germany, as well as in the equivalent bed, the Kupfermergel, in Poland. Nor is this the whole picture. Much wider areas of this bed have been found to carry significant amounts of lead and zinc; for example, its zinc content has been shown to exceed 5 kg./m² (0·9 per cent) over 5750 sq. km. Deans presents evidence that indicates that its base-metal content is abnormally high throughout the area of the Zechstein lagoon, that is, from the North of England to Poland. Space forbids a review here of the very large literature of this subject; it must suffice to express the opinion that it is most improbable that a shaly bed, less than 1 m. thick could be mineralised by late-magmatic solutions after consolidation, over this vast area.

Moreover, H. Schneiderhöhn[44] found upon microscopical study of this shale that pyrite and chalcopyrite occur in the form of minute spheres, aggregated into spherical and bar-like bodies up to 20 microns long. These he interpreted as fossil sulphur bacteria, with the tiny spheres representing the sulphur originally stored inside the organism. Comparable pyrite spheres have been found by Frebold[45] in the German Alum Shales while in the Kinnekulle oil-shale of Sweden, Bergh[46] has described similar bodies of which Schneiderhöhn states that all bacteriologists to whom he was able to show his preparations shared his opinion that they contain fossilised sulphur bacteria. Those in the Yorkshire Alum Shale have already been mentioned. They have been recognised in and adjacent to a number of important metalliferous ore-bodies, notably at Rammelsberg, Germany (in Devonian slate)[47] and at Mount Isa, Queensland (in late Pre-Cambrian black shale).[48] Pyrite occurs in similar tiny spheres in the Black Sea bottom muds, where it may be supposed to be due to the activity of *Desulfovibrio*. My own experience accords entirely with that of Deans (op. cit.) who says 'this is a normal and characteristic form . . . in many black muds, shales and other fine sediments . . . especially common in sapropels'.

Nevertheless, the bacterial origin of the spheres has been disputed by some, notably by Schouten,[49] who found the form and range of size of the spheres difficult or impossible to reconcile with the morphology of sulphur bacteria. A new and important development in this controversy has recently occurred. A. G. Love[50] has succeeded in isolating soft microfossils from pyrite spheres 2–30 microns in diameter from a Scottish oil-shale by dissolving the sulphide in nitric acid. He has erected two new genera and while he is in no doubt that these were anaerobic organisms, he does not think that they were bacteria. Thus, while bacterial activity may not be the explanation for all these tiny spherical bodies, a biochemical origin is still strongly indicated. From another point of view, it is very difficult to envisage any source of the sulphur in the pyrite of ordinary black shales if biochemical processes are not available to separate it from the sulphate of sea water, and from decaying organic matter.

It is suggested, therefore, that most if not all the pyrite and marcasite of black shale has a microbiological origin. High concentration of FeS_2 may be produced but if unaccompanied by other metals, few if any of them are workable as ores. Further concentration during metamorphism may convert the pyrite streaks and disseminations in black shales into concentrated pyrite or pyrrhotite lenses; but even this remains to be conclusively demonstrated.

When we turn to metals such as lead, zinc and copper, a further fact of common observation is the presence of galena, sphalerite and a variety of copper sulphides scattered about in very minor amounts in black shales, often in association with chalybite nodules of supposed diagenetic origin.[51] This is the normal situation. Compared with the common occurrence of unmetamorphosed black shales of all ages, in all parts of the world, the number of base metal ore deposits that have been found interbedded in rocks of this lithology or even in their lightly metamorphosed equivalents is very small. The list would include, in addition to the Kupferschiefer, the White Pine copper deposits of Michigan, the Rhodesian Copper Belt, Rammelsberg, Meggen and possibly Mount Isa; but substantial as these deposits are, their bulk is insignificantly small when compared with that of all the black shale formations. It follows from this that some highly special condition is required to produce such ore deposits.

Given a source of copper, lead or zinc, the deposition of the metal as sulphide by microbiological means similar to that of the pyrite normally present appears to offer no difficulty.

Indeed L. G. M. Baas Becking and D. Moore[52] have succeeded in precipitating most of the common metals, including lead, using cultures of *Desulfavibrio desulfuvicans*. It is now quite certain that bacteria are capable of precipitating many of the useful metals; the question that remains is, what is the source of the metals?

In the German literature, a possible solution was suggested as long ago as 1918, when W. E. Schmidt[53] proposed that the pyrite–spahlerite–barite ore-body in the Devonian rocks at Meggen, Westphalia, was the result of mineral springs erupting into a region of stagnation on the sea floor. This 'submarine-exhalative' hypothesis has found an eloquent advocate in Schneiderhöhn,[54] has been further elaborated by Ehrenburg[55] for Meggen, and also applied to Rammelsberg. Until very recently, although I had long ago canvassed the suggestion that the waste juvenile waters of the Hercynian mineralisation found their way into the Zechstein lagoon,[56] it had received very little attention in the English-speaking countries. Now, however, the submarine-exhalative hypothesis has champions in R. L. Stanton,[57] who lays considerable stress on the connection between concordant sulphide bodies and submarine volcanic activity, and D. Williams.[58] It seems to me to offer the most satisfactory explanation of the Kupferschiefer–Marl Slate mineralisation even though this is not connected with submarine volcanoes. The course of events may be envisaged as follows. Stagnation, partial or complete, had been effected as a result of the geographical changes leading to the beginnings of the Zechstein lagoon; humic material was being brought into the lagoon by rivers, and the conditions in the upper waters enabled fish to live in large numbers, feeding on floating marine plants. Pyrite or hydrotroilite was forming under microbiological influence in the bottom mud. Springs connected with the hydrothermal mineralisation then in progress in the Harz, the Thuringer Wald, the English Pennines and possibly elsewhere broke through into the lagoon, discharging a large volume of mineralised water left over after producing the extensive epigenetic deposits in those districts, adding the heavy metals not normally found in quantity even in a highly-evaporating lagoon. The metals were deposited either bacterially or by reaction with iron sulphide already present. A mass death of fishes may have occurred when the poisonous waters rose into the planktonic zone; T. S. Westoll[59] has shown that cartilage in some of the fishes was replaced by copper minerals indicating that copper was available early in the decay process. On the most recent evidence, the time relationships appear reasonable.

It might be argued that for juvenile springs to enter a limited region of lagoonal stagnation demands a high degree of coincidence; but to this it may be replied that all great ore deposits demand exceptional concurrences of favourable geological factors.

The copper deposit at White Pine, Michigan, shows many features in common with the Kupferschiefer. The Nonesuch Shale, of late Keewenawan (Pre-Cambrian) age is a cyclical series of sediments with sandstone, siltstone and black shale; the copper occurs in the form of chalcocite (Cu_2S) and native copper, chiefly in two black shale horizons 1 to 3 m. thick, the extent of which is measurable in square kilometres. A little copper also occurs in the sandstones. The mineralisation, according to W. S. White and J. C. Wright[60] appears to be independent both of structure and permeability; it occurs in impermeable beds in an otherwise highly permeable sequence, as in the Kupferschiefer. White and Wright think that a syngenetic or diagenetic origin is more likely than an hypothesis requiring post-lithification mineralisation.

The great copper deposits of Northern Rhodesia on which a symposium edited by Mendelsohn[61] is the most recent comprehensive work, occur partly in lightly metamorphosed shale (argillite), only part of the shale carrying the ore; and also in sandstone. The oreshoots are strictly concordant, thin relative to their huge sizes, and the copper mineralisation would cover many hundreds of square kilometres if the post-mineralisation folding were straightened out. Garlick (in Mendelsohn[61]) has pointed out the analogy with the Kupferschiefer, and has advocated transport of the copper by rivers, precipitation in stagnant conditions under biological influence, and zoning (barren–chalcocite–bornite–chalcopyrite–pyrite) away from the shoreline of the time. The ore-bodies are in many instances found in what were original gentle hollows in the surface at the time of deposition of the ore-bearing shale. A syngenetic or diagenetic origin for these deposits, which exhibit all the characteristics enumerated on p. 11, would seem

Fig. 4.—Oblique air photograph of Mount Isa mines, Queensland, where lead–zinc and copper orebodies are worked in steeply dipping black pyritic shales.

to offer less difficulty than one of introduced mineralisation, but there is a sharp division of opinion on the subject and my own lack of personal acquaintance with this area in the field forbids that I should enter further into the controversy.

The Mount Isa lead–zinc deposits (Fig. 4), most recently described by S. Carter[62] occur in a thick formation of black dolomitic shale which can be traced for over 40 km. along the strike, and which is rich in microspherical pyrite. The galena–sphalerite ore-bodies are tabular, parallel to the bedding, but some of them exceed 60 m. thick, as compared with a maximum strike length of the order of 750 m. N. H. Fisher,[63] who has recently reviewed the arguments on both sides, has concluded in favour of a syngenetic origin for these deposits; but it must be noted that they are very much less extensive than the enclosing pyritic shale; thus their thickness would imply long-continued enrichment in heavy metals in a few localised parts of the lagoon or sea in which the shale was deposited. This might be urged as an argument in favour of juvenile spring activity, but since there are copper ore-bodies in the same mine which, since they are mineralised breccias, can hardly be other than epigenetic, the Mount Isa problem needs to be approached with great caution. Other Australian examples of concordant sulphide bodies containing microspherical pyrite have recently been described by G. Baker[64]; he finds that, as at Mount Isa, the pyrite spheres always pre-date the ore minerals, but concludes that the full answer to the genetic problem has not yet been found.

Within more highly metamorphosed terranes, there are many more examples of concordant sulphide bodies. The Boliden and other deposits of the Skellefte district of Sweden, the Ammeberg district, Outukumpu (Finland), Captain's Flat, New South Wales, and the numerous massive sulphide bodies of the Canadian Shield may be cited as examples. V. P. Sokolov[66] remarks: 'The content of admixtures in metals is stable in sedimentary rocks and it has a regional character, in distinction from hydrothermal deposits where it is local and is subject to abrupt fluctuations. The sulphides become liberated, more or less, from their impurities, by virtue of their re-deposition during metamorphism of sedimentary rock.' V. Marmo[65] has recognised in Scandinavia a class of sulphide-graphitic schists which are the metamorphic equivalent of sapropelic pyritic shales. He urges that these are the primary source of the ore-forming material of the concordant sulphide bodies, which are formed when mobilisation

results from earth deformation accompanied by the activity of heated waters. A quantitative assessment of this interesting possibility is now required; indeed the whole problem of the relationship of base metal ore-bodies to black shale would greatly benefit from regional and detailed geochemical studies. The subject is only in its infancy.

Conclusion

Black mud can be observed forming at present in swamps, estuaries, lagoons, silled marine basins and in hollows where stagnation prevails on the sea floor. The submarine hollows do not appear sufficiently large, at present, to enable the very extensive formation of black shale which has occurred at many periods in the past to take place, and no lagoon depositing black mud on the scale of the Kupferschiefer–Kupfermergel–Marl Slate is now known. To this extent, the principle of uniformity apparently breaks down; but only in scale, not in result. Widespread precipitation of iron sulphide is occurring at present in black muds in all these environments, and some uranium is accumulating, but what is not known is whether significant amounts of other metals are being precipitated as sulphides. On the whole the evidence of the past suggests that while a concentration of trace amounts of other metals may have been achieved in ancient black muds, high concentration of such metals as copper, zinc and lead was only produced where very special local circumstances prevailed. The special circumstance favoured in this address is the operation of submarine springs, releasing juvenile or hydrothermal fluids into a stagnant environment. It is not, of course, denied that there might be other special circumstances, such as, for example, the contribution to the sea of metallic elements eroded from an arid land-surface by rivers carrying them in abnormal amounts.

Stagnation under euxinic or comparable conditions, and/or the rapid deposition of sediment in organically-productive waters leads to the preservation of carbon and other biophile elements. By far the greater amount of these in black shale is preserved as stable kerogen, but sapropelic muds will yield kerogen capable of producing hydrocarbons on distillation. Some sapropelic muds also spontaneously produce hydrocarbons during sedimentation and lithification, and thus act as source rocks of petroleum; but they are perhaps not the most important of mother rocks.

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SIR JOHN COCKCROFT, O.M., K.C.B., F.R.S.

PRESIDENT OF THE ASSOCIATION

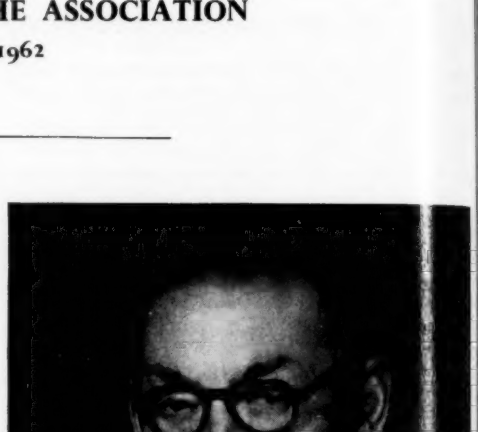
1961–1962

Sir John Cockcroft was, on August 30, 1961, elected President of the British Association for the Advancement of Science for the year 1961–1962. He will, thus, preside at the Association's 124th Annual Meeting which will take place in Manchester from August 29 to September 5, 1962.

The announcement made earlier this year, of the selection of Sir John to receive the Atoms for Peace Award said:

Sir John's contributions to the peaceful uses of the energy within the atom range from the first demonstrations that this energy can be released by man's ingenuity and skill to the direction of the development of full-scale nuclear-powered generating stations supplying electricity to England. He has taken a leading part in the development of large-scale test reactors, in the organisation and direction of one of the great research centres for the exploration of the peaceful uses of atomic energy at Harwell, in the distribution of radioactive isotopes for research and for medical therapy to many countries throughout the world, in the organisation of a Middle Eastern Nuclear Research Centre in Teheran (for the application of radio-isotopes), in the organisation of the Geneva Conferences on the Peaceful Uses of Atomic Energy under the sponsorship of the United Nations, in the training of scientists and engineers from many parts of the world at the school for the study of isotopes founded at Harwell, and in the discussions among scientists and diplomats about the ways in which the potential for benefitting mankind made available through atomic power can best be realised.

Sir John's career—thus outlined—began at Todmorden where he was born in 1897. After an outstanding career at Todmorden Secondary School, he proceeded to Manchester University in August 1914, but war service, first with the Y.M.C.A. and then, on the attainment of military age, with the Royal Field Artillery in France, interrupted his University career. As a gunner he survived the Somme, Passchendaele and Cambrai



battles; he himself has said that he felt that his three years in the army had deepened and increased his capacity for scientific work rather than damaged it.

On his demobilisation he returned to Manchester, where, under the influence of the late Prof. Miles Walker at the College of Technology, he developed that association with practical electrical engineering which has been so prominent a feature of his later career. After graduating at Manchester he spent two years as a College Apprentice with Metropolitan Vickers before proceeding to Cambridge University, there to develop the foundation laid at Manchester.

At Cambridge he had a distinguished academic career which culminated in his election as a Fellow of St. John's College in 1928 and his appointment as Junior Bursar to the College in 1933. Whilst at Cambridge, Dr. Cockcroft (as he then was), came under the powerful influence of the personality of the late Lord Rutherford, who was then developing the Cavendish Laboratory and gathering round him the brilliant circle of young physicists whose subsequent work will go down in history.

It was at this time that Dr. Cockcroft achieved world fame by his work, along with E. T. S. Walton, in breaking the atomic nucleus by artificial means, an achievement which was regognised by his election as a Fellow of the Royal Society and the award of the Hughes Medal. Of this work, which must have been intensely exciting, Sir John has said:

> We made two towers of glass petrol-pump cylinders which we stuck together with plasticine and pumped out to make a very good vacuum inside. One of these towers produced a very high voltage—300,000 or 400,000 volts. The other was our atomic gun down which our hydrogen atom bullets travelled, speeded up by the high voltage from the first tower.

Falling on a target of lithium, a few hydrogen bullets out of many millions struck home and ruptured the atoms of lithium into pairs of helium atoms. Thirteen years before, Rutherford had shot helium atoms at nitrogen and produced oxygen, but then he used the natural bullets from radium; Cockcroft and Walton had done it artificially and had uncovered 'a large and valuable fragment of the philosopher's stone'. Rutherford would point with pride at the almost crude apparatus which Cockcroft and Walton had made. He would remark, however, that the atom was always going to be a sink of energy and never a reservoir—more would be spent in splitting atoms than would ever be realised.

In 1939 Sir John was appointed Jacksonian Professor of Natural Philosophy at Cambridge—but the war was about to begin and, in September of that year, he was mobilised along with the country's entire scientific strength. One of his first tasks—along with his scientific colleagues—was to set up a chain of radar stations to detect low-flying aircraft from the Shetlands to the Thames Estuary. He demonstrated his remarkable gifts as an administrator by completing the complicated assignment in six months. That was part of his contribution to the winning of the battle against low-flying air attack. There followed a seven-year spell of ceaseless travel and effort. He visited the U.S.A. in 1940 as Deputy-Chairman of the Tizard Mission where, 'as a sort of scientific ambassador', he was largely responsible for that mobilisation and close co-operation of the British and American scientific resources which profoundly influenced the subsequent course of the war.

Sir John was a member of the M.A.U.D. Committee and played some part in securing the interest of Government circles in the possibility of Atomic Bombs. From 1944 as Director of the Montreal and Chalk River Laboratories of the National Research Council of Canada, he was responsible for the development of the Heavy Water Reactors at Chalk River and in 1946 was appointed Director of the Atomic Energy Research Establishment at Harwell. From 1952 to 1954 he was, in addition to his work at Harwell, Chairman of the Defence Research Policy Committee of the Ministry of Defence. When the responsibility for atomic energy research and development passed from the Ministry of Supply to the United Kingdom Atomic Energy Authority in August 1954, Sir John was appointed one of the full-time members of the Authority.

Most recently—in 1959—Sir John was appointed Master of Churchill College, a new foundation in the University of Cambridge established primarily to advance study and research in science and technology, but with 30 per cent of its students taking Arts subjects.

Sir John's many honours have included the award of the Nobel Prize, the Hughes Medal and the Royal Medal of the Royal Society, the Medal of Freedom of the United States, the 1961 Atoms for Peace Prize and—in 1957—the rare honour of the Order of Merit.

The British Association is honoured to have as its President not only a scientist of such distinction but one also who so clearly regards it as part of his duty as a scientist to explain to the public the significance of science—and to help prepare it for the world of tomorrow.

LOOKING AT science

FILMS ON PHYSICS

We list below details of those films concerned with aspects of Physics which have been shown at receptions for teachers of the subject arranged by the British Association in co-operation with industrial organisations.

It should be emphasised that at these receptions, the film programmes have been deliberately chosen to give a broad view of the available material and to show teachers many different types of film concerned with their subject. Whilst, therefore, some of the films listed below were specifically designed for class-room use, many are of a type which provide background information in a form suitable for a wide range of audience.

Some of these films would be useful for teaching, others can find a place in the programme of a Science Club or Film Society, and some might usefully serve as a starting point for discussion between Arts and Science students.

CONQUEST OF THE ATOM

Sound colour 30 minutes Gt. Britain 1958

Produced by the Realist Film Unit for Mullard Ltd., in co-operation with the Educational Foundation for Visual Aids and available on hire from the Foundation Film Library, Brooklands House, Weybridge, Surrey.

An account of the scientific investigation which led to the development of nuclear fission as a source of energy. The film describes the work of Thomson and Rutherford in determining the structure of the atom and discusses the subsequent contributions of such scientists as Chadwick and Cockcroft. Intended for a wide audience, this film is also useful as a convenient summary for Secondary School students.

COULOMB'S LAW

Sound black & white 28 minutes U.S.A. 1959

Produced by the Physical Science Study Committee. Not available in Great Britain.

A lecture demonstration by Eric Rogers of Princeton University, showing the inverse square variation of electrical force over distance, and illustrating that an electrical force is directly proportional to the charge. This is one of a series of physics teaching films designed for Secondary School children in America.

DISCHARGE THROUGH GASES

Sound black & white 11 minutes Gt. Britain 1958

Produced by the Educational Foundation for Visual Aids in conjunction with Mullard Ltd., and available on hire from the Foundation Film Library, Brooklands House, Weybridge, Surrey.

Discharge lighting, thyratron valves and electronic counting tubes are all dependent in operation upon different phenomena that are caused when electric currents pass through gases. Different effects can be achieved by varying the type of gas and the gas pressure. The film uses simple experiments to describe these different effects and explains their significance. Designed for advanced science teaching.

AN INTRODUCTION TO COMMINUTION

Sound colour 32 minutes Gt. Britain 1960

Produced by Film House Productions for International Combustion and available on free loan from G.B. Film Library, Aintree Road, Perivale, Greenford, Middlesex.

Comminution is the process of reducing particle size by breaking, grinding and crushing.

This is a technique used in a very wide variety of industries ranging from cosmetics to gold, and coal to chemicals.

This film surveys the early development of this ancient process and discusses some modern applications, showing the great variety of equipment devised to produce particles to many sizes.

Particularly useful for technical teaching and as background information for secondary school students.

AN INTRODUCTION TO JET ENGINES

Sound colour 14 minutes Canada 1959

Produced by the National Film Board of Canada, and available on hire from the Central Film Library, Bromyard Avenue, Acton.

An animated account of the principles of jet propulsion. This film was designed for training in the Royal Canadian Air Force.

A good, simple, technical exposition.

INTRODUCTION TO OPTICS

Sound colour 23 minutes U.S.A. 1960

Produced by the Physical Science Study Committee. Not available in Great Britain.

This is one of a new series of physics teaching films designed for Secondary School use in America. It provides a demonstration lecture by E. P. Little of the effects of defraction, scattering, refraction, and reflection on the distribution of light rays. One of a series designed for physics teaching in American secondary schools.

THE INFORMATION MACHINE

Sound colour 11 minutes U.S.A. 1959

Produced by Charles and Ray Eames and available for hire from the G.B. Film Library, Aintree Road, Perivale, Greenford, Middlesex.

A light-hearted account of the history of human thought and the contribution the computer can make to storing, analysing and using the mass of data which confronts man today. The computer can simulate unrealised situations such as rocket behaviour, aeroplane performance, the work of a complex chemical plant or even the behaviour of whole communities. Useful background information for students and a welcome addition to a science club or film society programme.

THE INVISIBLE FORCE

Sound colour 24 minutes Gt. Britain 1960

*Produced by Multifilm for Mullards Ltd., and available on free loan from Mullard Ltd., Mullard House, Torrington Place, London, W.C.*1.

A popular account of magnetism, which includes demonstrations of the ways in which science discovered its existence, and how by fundamental research industry has revealed more of the nature of this force. The film makes reference to new magnetic materials, such as Magnadur, Ticonal and Ferroxcube. For background information.

THE MANUFACTURE OF JUNCTION TRANSISTORS

Sound black & white 21 minutes Gt. Britain 1959

*Produced by the Mullard Film Unit and available on free loan from Mullard Ltd., Mullard House, Torrington Place, London, W.C.*1.

This film shows, stage by stage, the production of the junction transistor, from the achievement of the highly critical state of purity in the basic material, germanium, to the final testing of the finished transistor. It demonstrates how, with the use of ingenious machinery, intricate laboratory techniques have been applied to quantity production. For background information.

MOVEMENT AND TIME

Sound colour 14 minutes Czechoslovakia 1958

*Produced by Vosahlik for the Czechoslovak Popular Science Film Studios, and available on free loan from the Czechoslovak Embassy, 7 Kensington Palace Gardens, W.*8.

A popular account of Einstein's Theory of Relativity, designed for presentation to general audiences. Useful as an elementary introduction to a complex subject and perhaps as a point starting for discussion between science and arts students.

Would also interest film societies because of its examples of trick photography.

PAN-TELE-TRON

Sound colour 10 minutes Gt. Britain 1957

*Produced by Pearl and Dean for Phillips Electrical Co., and available on free loan from Sound Services, Wilton Crescent, London, S.W.*19.

A light-hearted account of the progress of communication and the contribution made today by tele-communications. Useful for film society and science club programmes.

PRINCIPLES OF X-RAYS

Sound black & white 17 minutes Gt. Britain 1960

Produced by Mullards Ltd. in collaboration with the National Committee for Visual Aids in Education, and available on hire from the Foundation Film Library, Brooklands House, Weybridge, Surrey.

The latest addition to the 'Advanced Science Series'. This film provides an animated explanation of the nature of X-rays in terms of atomic physics. It deals with the generation of X-rays, and shows some of their modern applications.

For 'A' level students.

REPORT ON RESEARCH NO. 1—FLOWING SOLIDS

Sound colour 17 minutes U.S.A. 1958

Produced by Campus Film Productions for Esso Research and Engineering Company and available on free loan from the Esso Petroleum Co. Ltd., 36 Queen Anne's Gate, S.W.1.

The use of solid catalysts in a continuous process such as petroleum catalytic reforming presents many problems. This film compares the behaviour of liquids with that of a solid into which air is injected. Designed for a non-specialist audience, this film would also be a useful introduction for 'O' and 'A' level students.

SCHLIEREN

Sound colour 19 minutes Gt. Britain 1959

Produced by the Shell Film Unit for Shell International Petroleum. Available on free loan from the Petroleum Films Bureau, 29 New Bond Street, London, W.1.

Made in answer to many enquiries about the system of photography used to study in colour the movements of air round objects in a wind tunnel, this film not only describes this photographic technique, but also demonstrates some homely applications in the field of physics. It was awarded a Diploma of Merit by the British Association in 1959 and would be useful not only for physics students but for science clubs, film societies and discussion groups of arts and science students.

THE STORY OF THE MOTOR CAR ENGINE

Sound colour 9½ minutes Gt. Britain 1959

Produced by Industrial Animation Films for the Ford Motor Co., and available on free loan from the Ford Motor Co., Regent Street, London, W.1

A very original cartoon treatment of the principles of the internal combustion engine which cleverly combines humour with teaching. This would be useful not only for teaching but also for extra curricular work of all kinds.

THIS IS AUTOMATION

Sound colour 30 minutes U.S.A. 1958

Produced by Raphael Wolf Productions and available free from the International General Electric Co., of New York Ltd., 296/302 High Holborn, London, W.C.1.

A film survey of some aspects of the development of automation in America since its first application in Oliver Evans' water mill in 1783. Intended to encourage firms of all sizes in every industry to investigate the possibility of applying automation to some part of their plans. This film would be useful, not only to show physics students the practical applications of scientific techniques in industry, but also to stimulate discussion among students of economics and economic history. It also provides useful general background information for science club and film society audiences.

B.A. RECEPTIONS FOR SCIENCE TEACHERS

Since details were last given in the March issue of this journal, six receptions have been held for teachers in areas as far apart as London and Dundee. Two were held with the co-operation of the National Coal Board, two with the co-operation of Associated Companies of Unilever, one with the National Cash Register Co., Dundee, and the other with the Henry Balfour Group of Companies in Leven.

This series has included not only further development of receptions on already established lines, but the introduction of more specialised receptions which will further widen the scope of this type of activity.

The display of charts and distributors' catalogues at the reception arranged with Unilever (Merseyside) Ltd.

With Unilever (Merseyside) and British Oil and Cake Mills, Glasgow, receptions were held for teachers of all branches of Science and suitable programmes of films were arranged to embrace the three main groups of scientific subjects. The Durham Division of the National Coal Board provided facilities for a reception of teachers of technical subjects. Completely new ground was broken, however, with the reception arranged with headquarters of the National Coal Board at their cinema in London. Here, the invited guests were headmasters and officers of local Education Authorities, and the purpose of the reception was to show them the use the National Coal Board makes of films and other visual aids, not only for internal training but also in the fields of education and public relations.

The Tayside Area Committee was also responsible for two receptions of a specialised character. The National Cash Register Co. provided facilities for a reception of teachers from Technical Schools and Colleges, which was devoted to the theme of Automation. The guests saw an appropriate film programme which discussed not only technical problems but also the human problems implicit in mass production and they also had the opportunity of seeing something of the factory and hearing about its technical and production problems. The Henry Balfour Group of Companies provided facilities at their Research laboratories at Leven for a reception for Chemistry teachers which was devoted to the specialised theme of Distillation and Evaporation. Again an appropriate film programme was screened and the teachers were able to tour the laboratories and see some of the equipment at work.

These specialised receptions offer many interesting possibilities. The practising teacher is frequently unable to acquaint himself with the industrial applications and processes which he discusses with his students and the chance to explore specialised

aspects of their subject is welcomed both by the teachers and their industrial hosts.

The reception at the National Coal Board Headquarters of June 14 concluded the 1960–61 season and a comprehensive programme of receptions is being arranged on a national scale for 1961–62.

A Novel Experiment in School Television

The first of a series of school-to-school television transmissions to be presented in Great Britain was arranged in the spring term by High Definition Television Limited (a member of the Pye Group) in co-operation with Middlesex Education Authority, the Hayes and Harlington Divisional Executive Committees and the Governors of the two schools taking part in the experiments.

A physics master in the Hayes Grammar School was able to teach not only his own class but another class in Barnhill Secondary Modern School, two miles away. His lesson was covered by two industrial television cameras, one directly facing him and covering himself, his desk and the blackboard, whilst a second camera was used for enlarging small objects and providing close-ups during demonstrations. Where required a third camera may be linked to a 16 mm. film projector to provide additional film illustrations. Wearing a neck microphone the teacher is in direct contact with both classes, and by means of a headphone is also able to hear comments by the teacher in the Secondary Modern School and questions from members of his class.

At a press demonstration a lesson on sound was given to a mixed second-year class in the Grammar School, and to the boys of the senior class in the Secondary Modern School. The vibration of strings and the agitation of small plastic balls in the bowl of a loudspeaker were clearly enlarged upon the television screen, and the teacher was able, by means of a hand switch, to change the picture from himself to his demonstration equipment. In both classrooms a 2-foot parabolic dish containing a microphone was so placed that it could be aimed at individual pupils to pick up their comments and questions without their having to move from their places. In this way the teacher giving the lesson and the pupils in both classes were kept in close touch with each other. The pupils, particularly those of the Secondary Modern School were obviously impressed with this novel method of presentation, and claimed that it focused their attention more effectively than would have been possible in an orthodox lesson. The physics master recognised that the technique was one which could only have limited use, as many lessons in a course must still rely on 'chalk and talk'.

The Middlesex Education Authority and High Definition Television Limited both regard this as an experiment, and are not prepared to prejudge its problems and possibilities. The equipment in use would probably cost at least £10,000 and since only about six lessons had been given in this way at the time of the press demonstration, there is a lot to be learnt about correct techniques of presentation and ways of getting the most effective use from a very novel method of teaching.

The Education Authority is not alone in considering this a useful project for study and Sir David Eccles, the Minister of Education, commented after a visit to Middlesex, 'This is a very worthwhile experiment which must be taken seriously'.

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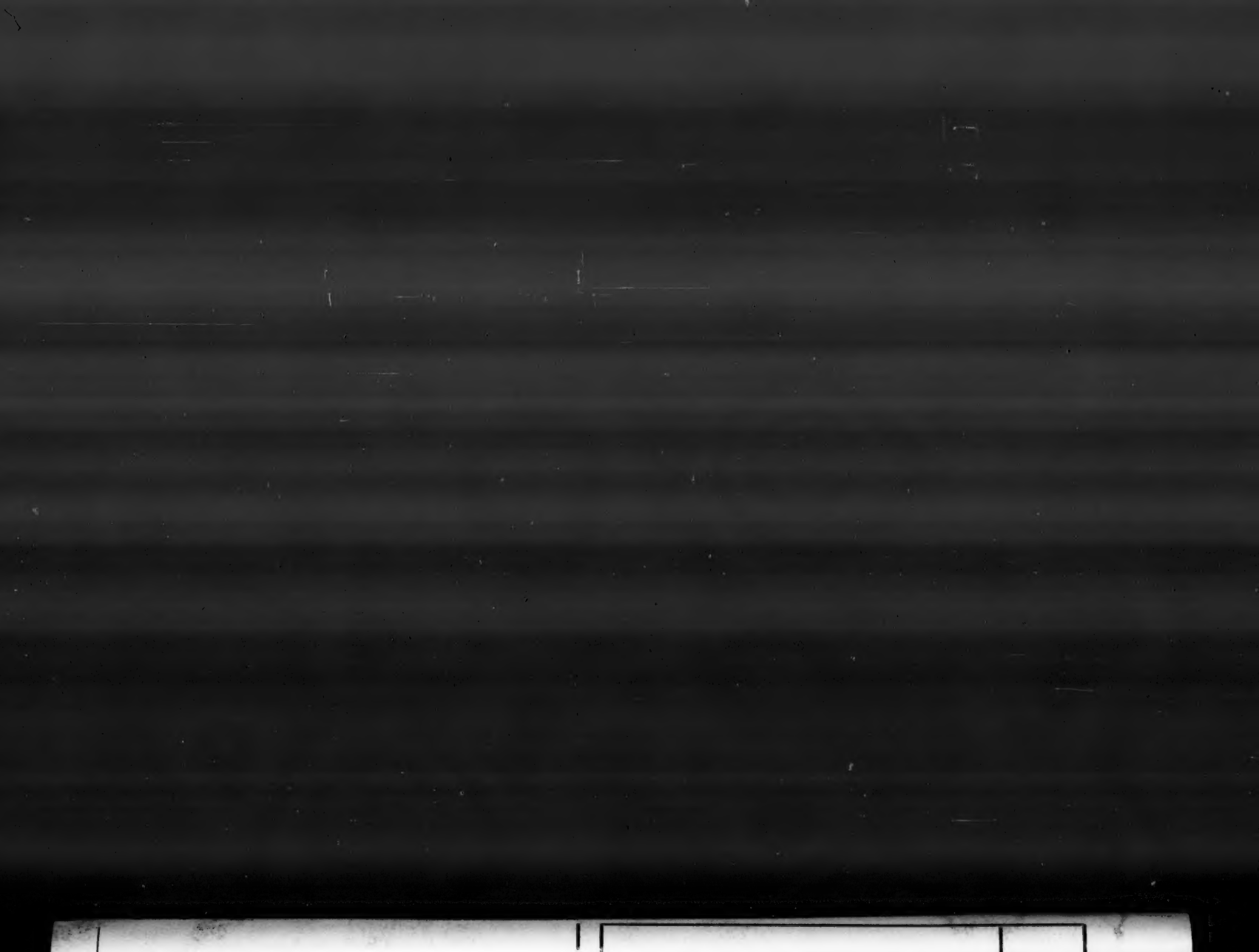
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